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study conducted at the pennsylvania state university,
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GUIDEBOOK FOR THE PLANNING OF INTEGRATED ATOMIC DEFENSE SHELTERS IN SELECTED MILITARY BUILDING TYPES

u. s. naval civil engineering laboratory,
port hueneme, california

$ 13.50

GUIDEBOOK FOR THE PLANNING OF INTEGRATED ATOMIC DEFENSE SHELTERS IN SELECTED MILITARY BUILDING TYPES

This guidebook as the product of a research study presents, in terms understood by architects and planners, information to enable such professionals to effectively plan integrated shelter as a part of the design of selected military building types. It was prepared by the following staff members of the Shelter Research and Study Program, Department of Architecture, College of Engineering and Architecture, The Pennsylvania State University, University Park, Pennsylvania:

Gifford H. Albright
Associate Professor of Architectural Engineering

Allen F. Dill
Associate Professor of Architectural Engineering

Rolv O. Enge
Assistant Professor of Architecture

Anthony H. Foderaro
Associate Professor of Nuclear Engineering

Walter K. Hill
Assistant Professor of Architecture

Melvin W. Isenberg
Associate Professor of Architectural Engineering

Lester L. Boyer
Research Assistant, Architectural Engineering

William A. Jaster
Graduate Assistant, Nuclear Engineering

Roger H. Kaness
Graduate Assistant, Architectural Engineering

General direction for preparation of the guidebook was given by Professor Albright, while general supervision and coordination was provided by Professor Dill. The preparation was carried out under the immediate supervision of Professor Enge as the Project Coordinator. The material was edited for the final presentation by Professors Albright, Dill, and Enge. Mr. William M. Duff was responsible for the format presentation and coordination and production of this document.

Respectfully submitted,

Rolv O. Enge

Rolv O. Enge
Project Coordinator

Approved:

Gifford H. Albright

Gifford H. Albright, Director
Shelter Research and Study Program

ABSTRACT

This study was designed to provide a guidebook which presented, in terms understood by architects and planners, information to enable such professionals to effectively plan integrated shelter as a part of the design of selected military building types.

The basic principles of the philosophy of protection, the philosophy of integrated convertible shelters, weapons effects, and architectural planning considerations are presented as background for the planning analyses and concepts for the integrated convertible shelters in several selected military building types.

This guidebook illustrates the point that integrated convertible shelters can be incorporated within conventional spaces of buildings without decreasing the efficiency of performing the normal functions or creating a windowless monstrosity and at little or no increase in cost. The military building types selected to illustrate the planning analyses and concepts are: Enlisted Men's Barracks, Training School, Administration Building, 100 Bed Hospital, Subsistence Building, and a Communications Building.

PREFACE

BACKGROUND

Atomic defense is of concern to many disciplines in todays technology. For example, the disaster control officer aboard a Naval Station is concerned with various operational aspects; the supply officer is concerned with disaster control equipment; the physicist is concerned with detailed, theoretical aspects of atomic weapons effects; and the public works officer, the architect, and the engineer are concerned with the planning and design of facilities aboard a Naval Station at which various weapons systems and personnel associated with such weapons systems are housed. In addition, many Naval personnel aboard a Naval Station are housed and trained for later assignment with the Fleet. There exist many documents describing operational aspects of atomic defense, single-purpose personnel protective shelters, and the effects of nuclear weapons; however, little study has been accomplished with regard to the planning aspects of protective spaces in new buildings in relationship to the conventional planning aspects of buildings. Consequently this guidebook evolved as a result of a research study contract, NBy-3188, between the U.S. Naval Civil Engineering Laboratory, Port Hueneme, California and The Shelter Research and Study Program of the College of Engineering and Architecture, The Pennsylvania State University, University Park, Pennsylvania.

OBJECTIVE

It is the objective of this guidebook to present, in terms understood by architects and planners, information which will enable such professionals to economically and effectively plan protection as a part of the design of selected military building types. Consequently, most of the information contained in the guidebook is of a fundamental architectural planning nature.

ORGANIZATION AND PRESENTATION

The guidebook is organized in two basic parts: (1) basic principles, and (2) applications. The first part is general in that it provides basic data relating to the problem of integrating protection into buildings without regard to building type. The second part is specific inasmuch as it refers to examples of selected military building types into which protection might be integrated with varying degrees of economy and effectiveness.

Chapter One serves as an introduction to the guidebook by including the philosophy of protection and the philosophy of integrated convertible shelter. Chapter Two provides data regarding the nature and effects of nuclear explosions. Chapter Three develops the formulation of the problem of protection, and general aspects of shelter planning—shelter needs, architectural planning considerations and illustrative planning solutions. Chapters

Four through Nine contain planning analysis and concepts for integrated convertible shelter in selected military building types—barracks, training school, administration building, hospital, subsistance building, and communications building. In these chapters guidelines and concept solutions are developed in order to give the planner a variety of thoughts and ideas regarding convertible shelter. The basis for the planning analysis of the military building types has been currently available (1960) definitive drawings issued by the U.S. Navy Bureau of Yards and Docks.

Chapters Four through Nine have been written to be essentially independent of each other; however, it is considered that Chapters One through Three are basic to the understanding of integrated convertible shelter and should be read prior to reference to Section Two, Applications.

A glossary is presented as Appendix A at the end of the guidebook. This contains brief definitions and descriptions of certain technical terms and concepts which are considered necessary to further amplify the statements in the guidebook.

Throughout the guidebook liberal use is made of diagrams and sketches in order to effectively illustrate in a graphic manner some of the systems, weapons effects, planning considerations, and concepts of integrated shelter.

LIMITATIONS

The guidebook is limited in the following ways:

(1) The information developed (other than weapons effects and shelter requirements) is not applicable for the special purpose or the single-purpose shelter.

(2) The guidebook is not applicable for areas other than for low level blast protection and protection against radioactive fallout.

(3) The guidebook does not include information of a nature needed for detailed engineering design of the subsystems, such as structural, electrical, and mechanical.

(4) The guidebook does not contain definitive drawings or prototype drawings for specific building types.

TABLE OF CONTENTS

PART ONE : BASIC PRINCIPLES

CHAPTER ONE PHILOSOPHY OF PROTECTION

BASIC CONCEPTS OF PROTECTION

In order to discuss the planning of shelter in buildings, it is necessary to first determine what is being protected against what effects.

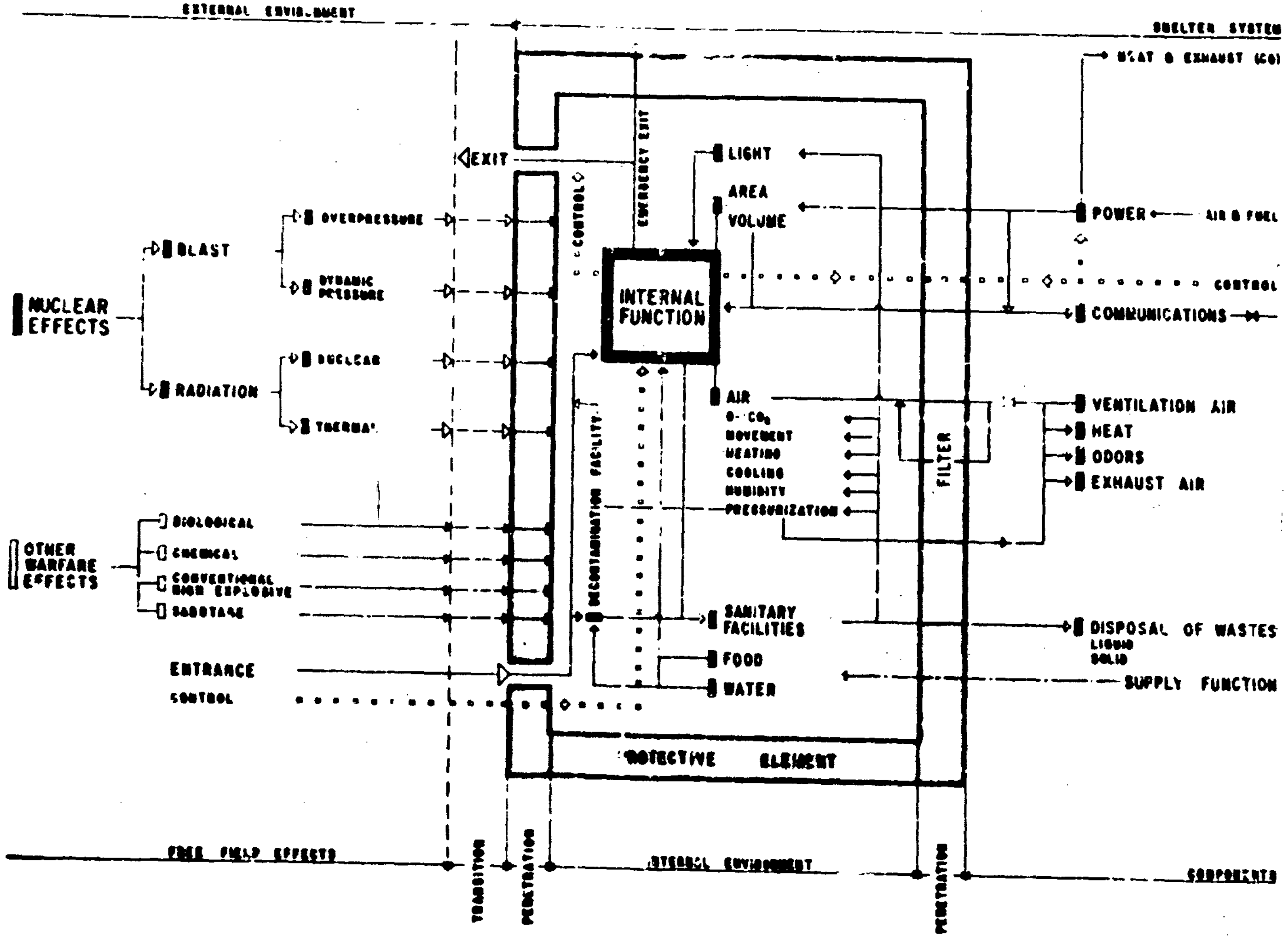
There are many degrees of protection against atomic weapons. Each degree of protection can be related to specific costs for specific levels of weapons effects.

Military personnel and varied items of military equipment could be provided with varying degrees of protection. For example, at one extreme one might protect all persons and all equipment from a direct hit of a thermonuclear weapon. At the other extreme, one might not provide any protection for personnel or equipment. Obviously, between these two ranges or extremes, there are many degrees of protection which can be provided. The determination of the degree of protection to be provided can be made on an operational or weapons systems basis; however, in many cases, the cost for the protection in relationship to the importance of that which is protected becomes a predominant factor.

The effects of general importance are blast, initial radiation, fallout radiation and thermal radiation. These effects are discussed in Chapter 2.

The planning and design of many weapons systems are of such nature that protection becomes one of the most predominant factors with regard to the success of the system. Therefore, protective requirements are basic in the planning and design. In those cases, the use of a specialized building or protective structures designed for protection against high blast and radiation levels is imperative. Such protection would be considered for key military functions close to probable target areas.

There are many other types of military facilities such as barracks and training schools, where the protection aspects of the design is subordinate to the function for which it is designed. Buildings of the types mentioned must function for their intended purpose; however, the fact should not be overlooked that it may be possible to provide protection in those buildings and not jeopardize their basic function. This type of protection may not provide the same results — circulation, functional efficiency, and protection as a specialized single-purpose protective shelter. Protection can be provided in "fringe areas", i.e., protection against low level blast and fallout radiation instead of high level blast and nuclear radiation. It is this "fringe area" protection, primarily from fallout radiation, which is of primary concern in this guidebook. Inclusion of such fallout protection provides a degree of inherent protection against low level blast.


EXTERNAL ENVIRONMENT
SHELTER SYSTEM
HEAT & EXHAUST (CO)
NUCLEAR EFFECTS
BLAST
OVERPRESSURE
DYNAMIC PRESSURE
RADIATION
NUCLEAR
THERMAL
OTHER WARFARE EFFECTS
BIOLOGICAL
CHEMICAL
CONVENTIONAL HIGH EXPLOSIVE
SABOTAGE
ENTRANCE
CONTROL
EXIT
EMERGENCY EXIT
CONTROL
LIGHT
AREA
VOLUME
INTERNAL FUNCTION
POWER
AIR & FUEL
CONTROL
COMMUNICATIONS
AIR
O - CO2
MOVEMENT
HEATING
COOLING
HUMIDITY
PRESSURIZATION
FILTER
VENTILATION AIR
HEAT
ODORS
EXHAUST AIR
DECONTAMINATION FACILITY
SANITARY FACILITIES
FOOD
WATER
DISPOSAL OF WASTES
LIQUID
SOLID
SUPPLY FUNCTION
PROTECTIVE ELEMENT
FREE FIELD EFFECTS
TRANSITION
PENETRATION
INTERNAL ENVIRONMENT
PENETRATION
COMPONENTS

NEED FOR SHELTER

Because of the damaging nature of fallout radiation to humans, it is necessary to stay within a protected area for extended periods of time (days). This means that provision for continuation of life within the protected area must be considered. Consequently, water, food, air, light, and sanitary facilities of an austere nature must be provided.

In order to provide such necessities various engineering systems must serve protected areas.

A schematic shelter systems diagram is included to illustrate the general protection problem — weapons effects, protective area, shelter needs, and engineering systems.

SHELTER TYPES

Shelters might be classified basically as single-purpose shelters and dual-use shelters. The single-purpose shelter would: (1) serve only as a shelter, (2) be designed, constructed, and maintained for use as a shelter, and (3) stand idle until needed for use.

The dual-use shelter would: (1) serve some function other than shelter, (2) be designed, constructed, and maintained for use other than shelter, and (3) serve many functions other than shelter until needed for shelter use.

The advantages fo the dual-use shelter over the single-purpose shelter on an economic basis are apparent. Because of its dual use, such protected area must satisfy many more diverse requirements; consequently, the planning and design problem is frequently more difficult. The term INTEGRATED CONVERTIBLE SHELTER is used to describe the dual-use space integrated into the basic function of a building, and which is converted into a shelter at the time of need.

INTEGRATED CONVERTIBLE SHELTER

It is possible to have a dual-use shelter in a space in a building already designed and constructed for a conventional purpose. Such space, because of its location within the building and relation to various utilities, could offer some protection and services for a prolonged shelter occupancy. On the other hand, if the designer of the building knew that the use of certain spaces for shelter was a requirement, it would be possible to integrate such a requirement into the basic design concept.

The space designed on this basis suitable for dual-use is called the integrated convertible shelter. Recognizing the need for shelter prior to the preliminary planning of the building provides an opportunity to provide a better shelter area.

HOW TO ATTAIN INTEGRATED CONVERTIBLE SHELTER

Up to the present, few planners and architects have been confronted with shelter requirements for protection nor have they needed to understand and visualize the influence of shelter requirements on the planning of various building types. It is important therefore, that the approach to attain integrated convertible shelter be developed on a step-by-step basis.

In order to provide effective integrated convertible shelter, it is necessary that protection be achieved without waste of space, jeopardy of function, or additional expense. Thus, the optimum requirements are summarized:

1. To provide effective emergency protection
2. To avoid a decrease of efficiency of the normal functions
3. To provide dual-functioning spaces
4. To cause little or no additional expense
5. To design a building that is not a windowless monstrosity because of the incorporation of shelter

If a building is planned, designed, and constructed with these five points in mind, one will find that there are many varied solutions to the problem of integration of shelter. Many conventional criteria and normal building requirements that are of a traditional and obvious nature may be worthy of considerations in a new light. Usually there is more than one satisfactory answer to the problem. A restudy of conventional requirements may thus give the key to the integrated shelter problem, and some of the factors to consider are: (1) location, (2) functional relationship, (3) materials surrounding functional spaces, (4) structural systems, (5) convenience to environmental service facilities, such as waste, food, filtered fresh air, heat, and power.

There are many spaces in most buildings that by restudy and good planning may be improved for normal functions and at the same time give opportunities for good shelter spaces. Such spaces that serve both normal and emergency shelter functions efficiently are potentially convertible shelter spaces. The term, Integrated Convertible Shelter will be used throughout this guidebook as shelter integrated within the building—function, structure, mechanical systems, and materials—to provide protection from radioactive fallout, low level blast effects, biological and chemical warfare. The term will be used whether the concept of the shelter is a core within a core, a basement, a basement with a core, or any other possible solutions as long as the above-mentioned requirements are considered.

This type of planning will require a thorough analysis of all functional uses of the building in question. Consequently, the basic approach to the attainment of integrated shelter will be:

1. A study and analysis of the functional requirements for normal operation

2. A study of the shelter requirements
3. Integration of normal requirements and shelter requirements into an operational and economical solution

Normal Operational Needs

Only with the integration of all elements can one create complete and total architecture. Thus it becomes important to analyze normal requirements. For example, the broad analysis might contain:

1. Functional

External and internal relationship of spaces.
Efficiency of operation.
Sociological and psychological considerations (environmental effects on man including color, material, sound, etc.)

2. Structural

Material
Loads
Span
Support

3. Environmental

Heating and Cooling
Ventilation
Sanitation

In this analysis it will become apparent that certain spaces will be more effective as interior spaces and hence depend entirely on artificial environment. Several examples for a training school are:

a. certain classrooms (music room, visual aids)
b. conference (seminar rooms)
c. storage
d. shops
e. toilets
f. corridors

Shelter Needs

The shelter needs can be divided into two basic categories:

1. The enclosure which provides adequate shielding against radiation and low-level blast, and
2. The environment within a protective envelope — needs such as food, air, water, heat, light, and sanitary facilities.

Integration

The collection and analysis of conventional building requirements and shelter needs are prerequisite to the development of the integrated shelter design.

The most important facet of shelter planning is planning for protection. The factors determining this protection are:

1. Barrier Effect - achieved by mass thickness or density of the shell separating the shelter occupants from exterior surfaces (ground, roofs, other buildings) on which fallout is deposited. This mass thickness can be achieved by either one or more of the following:

a. minimum apertures in exterior and interior walls, (baffling or other protective shielding may be used to increase protection),
b. as many walls and floors as possible between exterior contaminated surfaces and the protected area,
c. the selection of dense materials used for floor, wall, and roof constructions.

2. The Geometry Effect - the effects of distance of the shelter occupants from the source of radiation. This geometry effect is often an inherent factor in the planning of convertible shelter due to the location of the protected area.

From the above factors it is apparent that ideally a convertible shelter should not be planned along an outside wall, on the top floor, or first floor of a building, because of excessive expense for: (1) abnormal and wasteful thicknesses of roofs, floors, and exterior and interior walls, and (2) shielding of windows.

The desirability and the necessity of interior rooms and spaces for normal activities should be analyzed for various building types. It thus becomes obvious that the shelter capacity, protection factor, and shelter location will depend upon the planning of these interior spaces.

Space in some type of a core, or the use of the basement, or a combination, has specific characteristics necessary for an effective integrated convertible shelter.

In subsequent chapters of this guidebook, these basic principles will be further developed in greater detail. Their application is illustrated by means of example concepts for selected military building types.

CHAPTER TWO NUCLEAR WEAPONS EFFECTS

NUCLEAR EXPLOSIONS

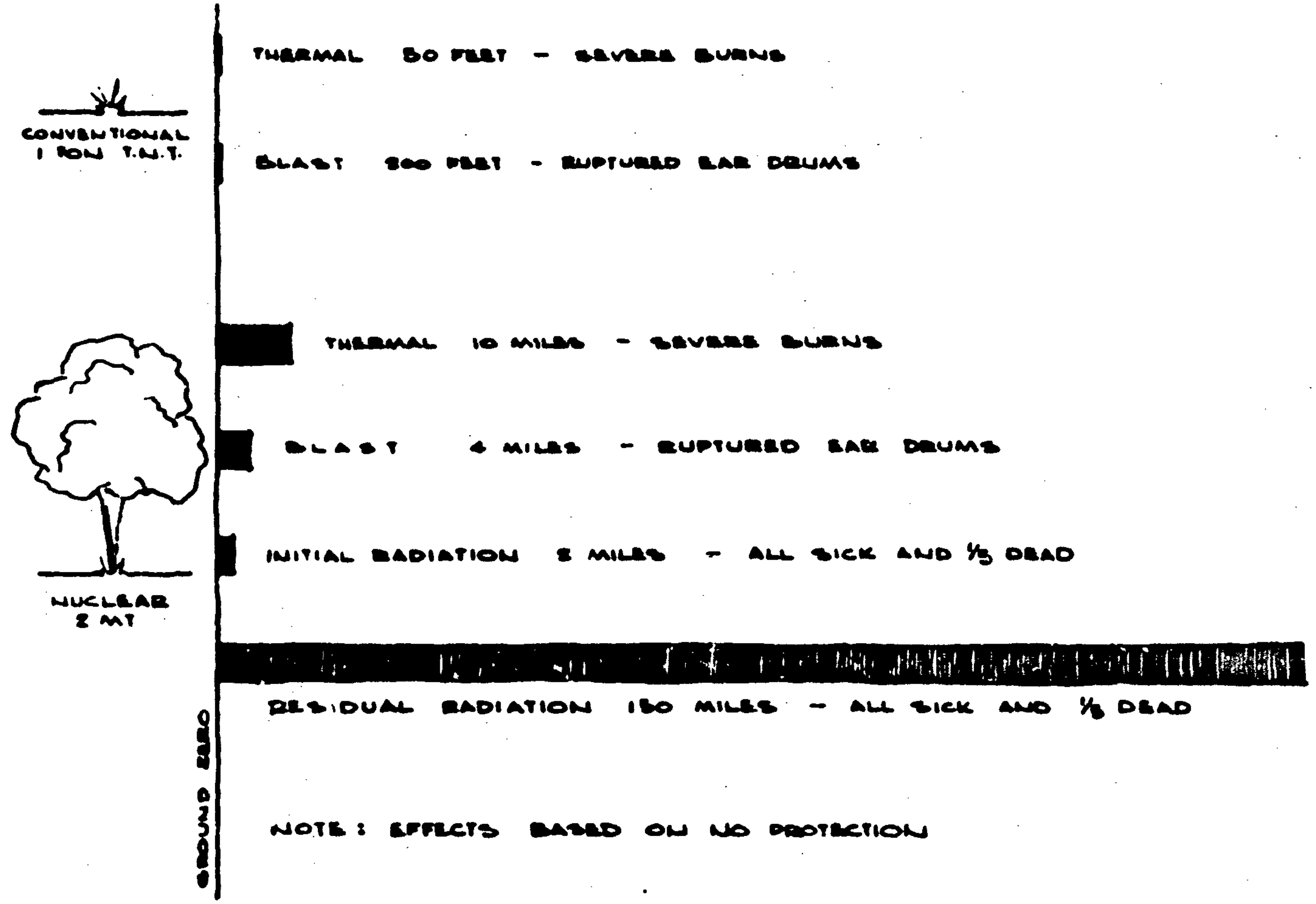
The objective of this chapter is to identify and dimension nuclear weapons effects and discuss their significance in relation to the architectural and engineering planning of buildings. As the material presented herein is restricted to information of an introductory nature, reference may be made to Appendix A — Glossary for a more quantitative and technical discussion. For a detailed explanation of the scientific basis of nuclear explosions, phenomena, etc., references should be made to "The Effects of Nuclear Weapons," U.S. Government Printing Office, Washington 25, D.C.

All types of explosions—industrial, conventional high explosive weapons, and nuclear weapons—release a tremendous amount of energy within a relatively confined space over a very short interval of time. This energy release is largely in the form of heat energy; a portion appearing as a flash of light and a heat wave, and a portion converting the explosion products into gases at extremely high temperatures. Inasmuch as these gaseous products are initially confined with a small volume, tremendous pressures exist. As the hot gases expand, a shock wave is developed which propagates outwards from the center of the explosion. This shock wave, or blast wave as it is more usually referred to, is very similar to a rapidly moving wall of water. As the wave encounters an object it engulfs the object with a resulting squeezing action and attempts to drag along the object with a resulting racking action.

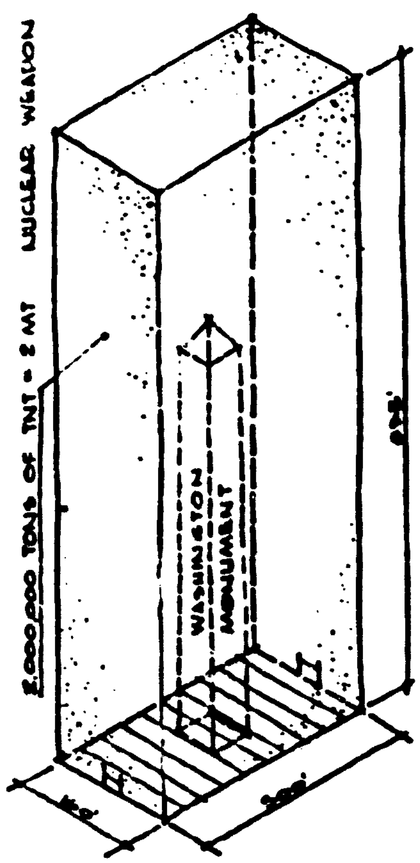
In addition to the fact that the total energy release of a nuclear explosion is many thousand times that of a conventional high explosive thus extending by many orders of magnitude the destructive range of the thermal energy and blast wave, the nuclear explosion is accompanied by two entirely unique weapon effects. These are the initial nuclear radiation and the residual nuclear radiation, commonly referred to as fallout radiation. Whereas the effects of conventional weapons are only of significance within several hundred feet of the detonation, the tremendously greater energy release and fallout of a nuclear weapon make its effects of significance to several hundred miles. Thus, weapons effects are no longer a point problem, but an area problem.

Because of these fundamental differences—the effects of nuclear weapons acquire special significance in the architectural and engineering planning of all buildings. Therefore, the remainder of this chapter will include the following items: energy released from nuclear weapons, the distribution of this energy as nuclear radiations (initial and fallout), thermal radiation (heat), and blast and shock (pressures); types of explosions (air, surface, and underground bursts); and the identity, dimension, and significance of these weapon effects as they relate to architectural planning.

The size of a nuclear weapon, referred to as its power or yield, is expressed in terms of the energy that is released by TNT. Therefore, a one-kiloton (1 KT) nuclear weapon releases an amount of energy equivalent to that released by one-thousand (1,000) tons of TNT, whereas a one-megaton (1 MT) nuclear weapon releases energy equiva-



COMPARISON OF CONVENTIONAL AND NUCLEAR WEAPONS



lent to one-million (1,000,000) tons of TNT. Nuclear weapons have been detonated with energy releases ranging from a fraction of a kiloton through the 20 kiloton weapons detonated over Japan to a 15 megaton weapon in the March 1954 test at the Marshall Islands in the Pacific.

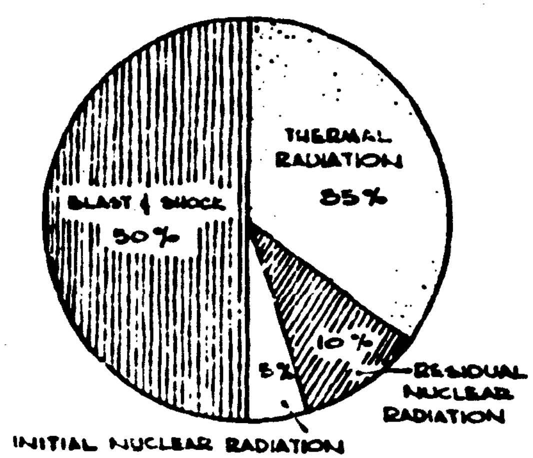
To describe the effects of large and small yield nuclear weapons, a 2 MT and a 100 KT weapon have been selectdd for illustrative purposes.

It would be necessary to detonate a charge of TNT stacked 825 feet high, (one and one-half times the height of the Washington Monument), with a base the size of a standard 160 foot by 300 foot football field to approximate the energy released by a 2 MT nuclear weapon.

In the explosion of a conventional [illegible] explosive (TNT) weapon, nearly all the released energy appears immediately as heat energy and is converted into blast and shock. However, in the explosion of a nuclear weapon, the distribution of energy is determined by both the type of construction of the weapon (fission, fission-fusion, fission-fusion-fission) and the type or location of explosion (air, surface, underground burst). While the fission process maximizes the nuclear radiation effects, the fusion process maximizes the blast and thermal effects. An air burst tends to maximize the blast, thermal radiation, and initial nuclear radiation, while minimizing the residual nuclear radiation. A surface burst maximizes the residual nuclear radiation, while minimizing the air blast, thermal radiation, and initial nuclear radiation.

The distribution of energy in a typical air burst of a fission weapon such as was detonated over Japan is as follows:

about 85 percent is in the form of heat energy, of which about 50 percent produces blast and shock, and 35 percent appears as thermal radiation (heat and light rays); 5 percent constitute the initial nuclear radiation produced within the first minute after an explosion; and 10 percent as residual nuclear radiation emitted over a very long period.



DISTRIBUTION OF ENERGY IN A TYPICAL AIR BURST OF A FISSION WEAPON

NUCLEAR RADIATION

The nuclear radiations emitted following the detonation of a nuclear weapon . . divided into two categories — initial and residual. The initial radiations (those emitted within 1 minute after the explosion) consist of gamma rays and neutrons capable of penetrating large distances in air and producing injurious effects in living organisms. Residual radiations, or fallout (those emitted after 1 minute) consist of alpha and beta particles and gamma rays capable of producing in varying degrees injurious effects in living organisms.

INITIAL NUCLEAR RADIATION

The initial nuclear radiation problem, like the blast and thermal radiation problems, is a local one seriously affecting only the area within a few miles of ground zero. For example, the initial nuclear radiations from a 2 MT weapon would probably cause no deaths to individuals beyond two miles from ground zero, affecting an area of perhaps only 12 square miles. In contrast, the residual (fallout) radiations can cause deaths hundreds of miles away, thus affecting areas of thousands of square miles. The following table lists the effects of initial nuclear radiation on exposed personnel in the open at various distances from 100 KT and 2 MT weapons. These effects decrease rapidly with distance and cause no serious radiation sickness even at 2 miles from a 2 MT weapon.

INITIAL RADIATION EFFECTS ON EXPOSED PERSONNEL

Effects*	Distance from Burst (feet)	
	100 KT	2 MT
LD 100	5100	8400
LD 50	5500	8700
LD 20 & SD 100	5600	9100
LD 0 & SD 50	5900	9300
SD 25	6100	9800
SD 10	6400	9900
SD 0	6900	10600

*Effects are expressed in terms of the percentage of the exposed population who would become sick or die. Thus, LD 50 or "Lethal Dose 50," means that 50% of the personnel would die, whereas SD 10 or "Sick Dose 10," that 10% would become sick.

Protection against initial nuclear radiations will not be considered in this guidebook except to note that shielding against neutrons is not accomplished by mass alone as it is with gamma rays. In order to slow down the fast neutrons so that they are eventually absorbed in the shield, it is necessary to include light elements, particularly hydrogen, in the shield. Whereas a given mass per unit area of lead is about as effective in absorbing gamma rays as the same mass per unit area of concrete, the lead would be much less effective in the absorption of neutrons than the concrete which contains water and therefore hydrogen.

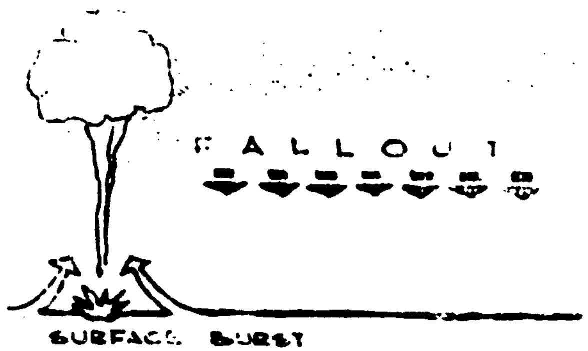
RESIDUAL NUCLEAR RADIATION (FALLOUT)

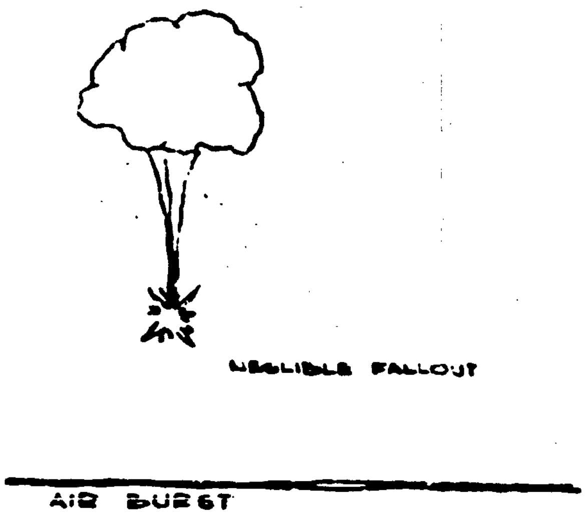
Production and Deposition of Fallout.

When a nuclear weapon is detonated on or near the ground so that the fireball contacts the ground, thousands of tons of pulverized and vaporized soil and other materials are carried into the atmosphere in the nuclear cloud. These particles are propelled by a strong updraft and will rise very rapidly to a great height. For example, within eight minutes following a 2 MT surface burst, the cloud may reach its maximum altitude of 70,000 to 80,000 feet. The cloud then contains vast quantities of dust particles to which radioactive atoms from the weapon will adhere. The dust particles range in size from visible bits and flakes to submicroscopic particles.

Radioactive fallout is the surface deposition of the radioactive material which has been formed and carried aloft by the nuclear explosion. These particles are then acted upon by two forces — gravity and the winds. The large particles settle to the ground rapidly, the smaller ones more slowly. The rate and place of fall depends on the particle's size, shape, and weight, and the wind speed and direction at various altitudes.

Under normal wind conditions, the heavier material will fall within an hour or two into a roughly circular pattern around ground zero. The lightest particles formed will enter the stratosphere and remain suspended for long periods and probably travel many thousands of miles before descending. The intermediate weight particles will probably reach





... earth within a few hundred miles of ground zero. The particles may be expected to form a generally elongated ... shaped pattern of contamination on the ground.

The Fallout Composition

The radioactive material which is carried in the fallout consists of: (1) fission products which are particles created in the fissioning of the material of the weapons; (2) particles made radioactive by the neutrons released at the time of the explosion —these particles may have been part of the weapon, casing, weapon triggering mechanisms, or earth and debris; and (3) the unfissioned uranium or plutonium of the weapon itself.

Types of Radiation

The unfissioned material generally emits alpha particles, whereas the fission products and the neutron—induced radioactive products are beta and gamma emitters. The alpha radiation may be ignored in the radiation shielding design for protection against fallout since it can be stopped by a thin layer of clothing or the skin itself. The alpha radiation can be a hazard if it enters the body either by ingestion, inhalation or through skin abrasions. However, even this usually may be ignored relative to the ingestion hazard posed by the much more numerous beta and gamma emitters.

Beta particles, which are high energy negative and positive electrons, can be dangerous both internally and ex-

ternally. The external problem is a relatively trivial one since beta particles are stopped by small thicknesses of solids, their range in wood, water or body tissue being only about a tenth of an inch. Thick clothing will also stop them. They are hazardous, however, when they come in direct contact with the skin or are ingested or inhaled.

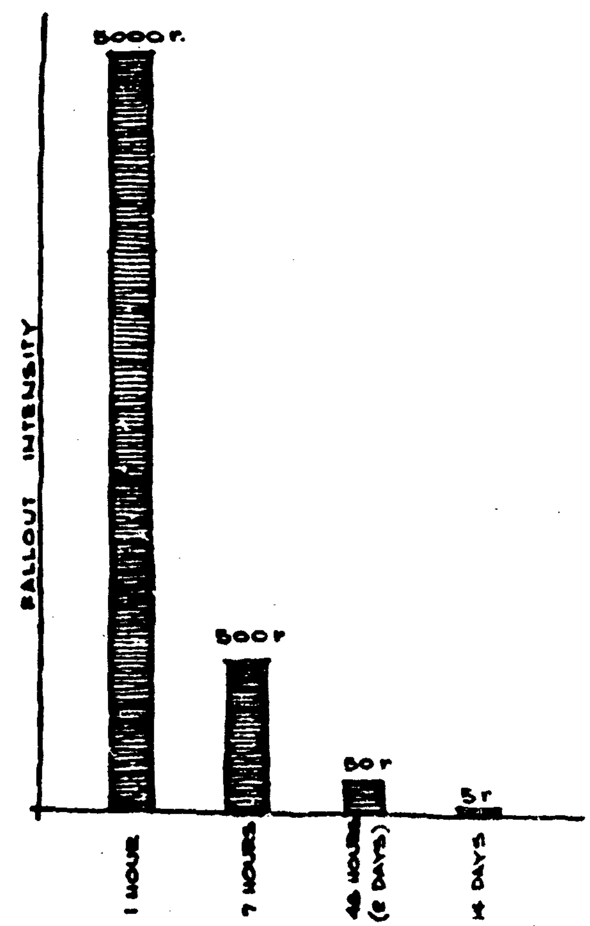
Gamma rays, which are high energy electromagnetic radiations like X-rays, are very penetrating and determine completely the amount of material needed for shielding against fallout. Radioactive fallout particles emit gamma rays varying in energy from y "soft" and easily absorbed to very "hard" and deeply penetrating. Even relatively thin shields afford some protection against the softer rays; however, adequate protec on against the more energetic rays may require considerable mass thicknesses of material.

THE BASIC REQUIREMENT FOR PROTECTION AGAINST FALLOUT IS TO PROVIDE A SHIELD AGAINST GAMMA RADIATION.

Such a shield will automatically protect against the beta radiation. The alpha-, beta-, and gamma-emitters must also be excluded from the protected area. This may necessitate both the decontamination of entering personnel and/or the filtration of air.

<u>Decrease of Fallout Activity with Time</u>

Beta and gamma rays are emitted by the nuclei of so-



DECREASE OF FALLOUT ACTIVITY WITH TIME

called "radio-active" atoms. In the process of emitting these rays a radioactive atom becomes a stable atom and identical with any other atom of its species and no longer constitutes a hazard. Thus the intensity of radiation from fallout constantly decreases or decays with time. Radioactive fallout decays by approximately a factor of 10 for every multiple of 7 in time. For example: if the gamma intensity of 5000 roentgen an hour after the burst, its value 7 hours after the burst will be down to 1/10 of 5000 or 500 roentgens; its value 49 hours (approximately 2 days) after the burst will be down to 1/100 of 5000 or 50 roentgen; its value 14 days after the burst will be down to 1/1000 of 5000 or 5 roentgen and so on.

BIOLOGICAL EFFECTS OF NUCLEAR RADIATIONS

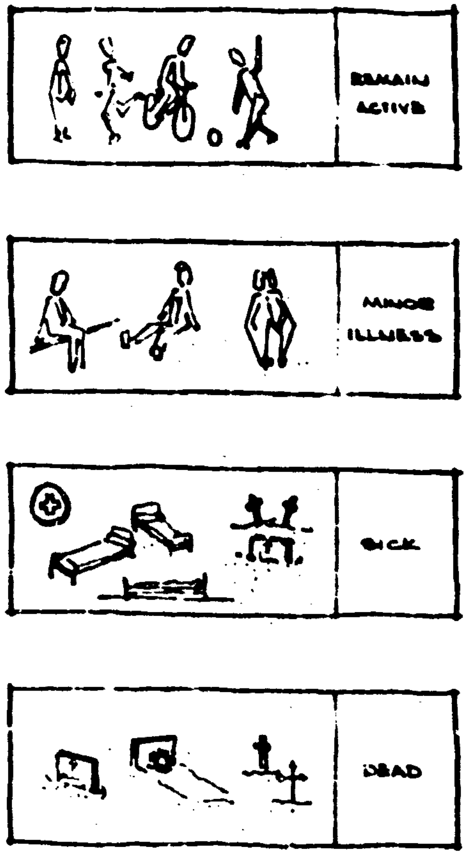
In general the biological effects of exposure to nuclear radiations result from the ionization of and damage to, molecules in the body tissue. The nuclear radiations of primary interest in the problem of protection are the gamma rays and neutrons.

The basic unit of exposure dose is the roentgen (r). The dose rate, intensity, measured in roentgens per hour (r/hr) is the time rate at which radiation dose is delivered; for example, a person exposed to a constant dose rate of 5 r/hr for 6 hours would be exposed to a total dose of 5 r/hr x 6 hr = 30 r.

Some of the effects of nuclear radiations on living organisms depend not only on the total dose, but also on the dose rate. For example, 700 roentgens over the whole body delivered in a short time (less than an hour) would almost inevitably prove fatal to a human. However, if the same dose were delivered over a long period (10 years), at a more or less uniform rate there would probably be no noticeable effects. The reason is that most of the cells damaged by radiation can be replaced by new cells provided the percentage damaged by radiation is not too high, recovery cannot keep pace with the damage and injury will result. Recent research indicates that a dose of 400 to 500 roentgens over the entire body in a short period leaves only about one half of the body's reproductive cells still able to multiply. Death, even in this case is not immediate. The cells have suffered considerable chromosomal damage but their enzymatic machinery is still relatively active. They continue to function in almost normal fashion until the time comes to reproduce and reproduction fails. This explains one of the most characteristic features of radiation injury: the lag that usually occurs between even severe exposure to radiation and the development of pathological symptoms.

Rather large acute radiation doses are not uncommon under ordinary circumstances. For example a fluorescent screen examination usually results in a received dose of 4 to 40 roentgens, and X-ray pregnancy examination may result in a dose as high as 70 roentgens. These are not, however, whole body exposures, so that the injury is less severe than the case for nuclear radiation.

Some of the biological effects of nuclear radiations are believed to depend on the total dose, even if delivered over long periods of time. It is estimated, very roughly, that a whole-body dose of 100 roentgens will reduce the life span by about a year and induce 30 percent more



BIOLOGICAL EFFECTS

2 MT. SURFACE BURST
WIND VELOCITY - 15 MPH

DOWNWIND DIST. IN MILES	50	100	150	200	250
TIME LAG FROM DETONATION TO ARRIVAL OF FALLOUT (IN HOURS)	3¼	6½	9¾	13	16¼
EFFECT ON UNPROTECTED PERSONNEL 14 DAY EXPOSURE	100 % LETHAL	100 % SICK 50 % LETHAL	25 % SICK	5 % SICK	NO OBVIOUS EFFECTS

EFFECTS ON EXPOSED PERSONNEL WITH TIME

mutations per gene than occur spontaneously.

The expected effects of acute whole-body radiation doses are illustrated on 2-9. They are based on observations made in Japan and the Marshall Islands.

The accompanying chart indicates for several downwind distances from a 2 megaton surface burst the effects of fallout on personnel exposed for 14 days without protection, and the delay in the arrival of the fallout after detonation. Two facts are immediately obvious:

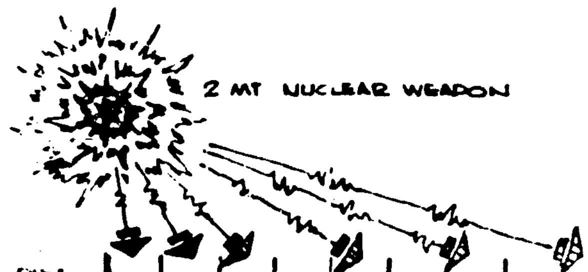
1 PROTECTION IS REQUIRED

2 SUFFICIENT TIME MUST EXIST FOR PEOPLE TO TAKE SHELTER AFTER A DISTANT DETONATION.

THERMAL RADIATION

Because of the enormous amount of energy liberated in a nuclear weapon, very high temperatures are attained. As a consequence of the high temperatures in the ball of fire, (similar to those in the center of the sun), a considerable portion of the nuclear energy appears as thermal radiation. For every 1 KT of the nuclear explosion, approximately 400,000 kilowatt hours of energy is released as radiant thermal energy within a second of the detonation.

Thermal radiation will contribute to overall damage by igniting combustible materials. In addition, it is capable of causing skin burns on exposed individuals at distances from the explosion where the effects of blast and initial



DIST. IN MILES	2	4	6	8	10	12	14	16	18
EFFECTS ON INDIVIDUALS					SEVERE SKIN BURN	BLISTERS			MILD SUNBURN
EFFECTS ON MAT'L & FURNISH.									
ACOUST. TILE		GLOWS							
1/4" PLYW'D			FLAMES						
UPHOLST. CHAIRS		BURNS	FLAMES						
ROLL ROOFING				FLAMES					

radiation are not critical. The thermal energy from a specified explosion received by a given surface will be less at greater distances from the explosion for two reasons: (1) the spread of the radiation over an ever-increasing area as it travels away from the fireball, and (2) attenuation of the radiation in its passage through the air. Unless scattered, the thermal radiation from a nuclear explosion travels like light in straight lines from its source—the ball of fire. Any solid, opaque material, such as a wall, a hill, or tree, located between the object and the fireball will thus act as a shield and provide protection from thermal radiation. Transparent materials, on the other hand, such as glass or plastics allow thermal radiation to pass through only slightly reduced in intensity.

The proportion of the energy appearing as thermal radiation will be greater for an air burst than for a surface burst—where the ball of fire actually touches the earth or water. In a sub-surface burst, either in the earth or underwater, nearly all the thermal radiation is absorbed by the earth or water.

The ignition of combustible materials by thermal radiation depends upon a number of factors, the two most important, other than the nature of the material itself, are (1) the thickness and (2) the moisture content of the material.

Damage to a building by fire caused by a nuclear detonation depends primarily upon the selection of construction materials and furnishings which are exposed to the thermal radiation. The thermal energies received will depend upon the size and location of the nuclear weapon as well as the orientation and line of sight "shielding".

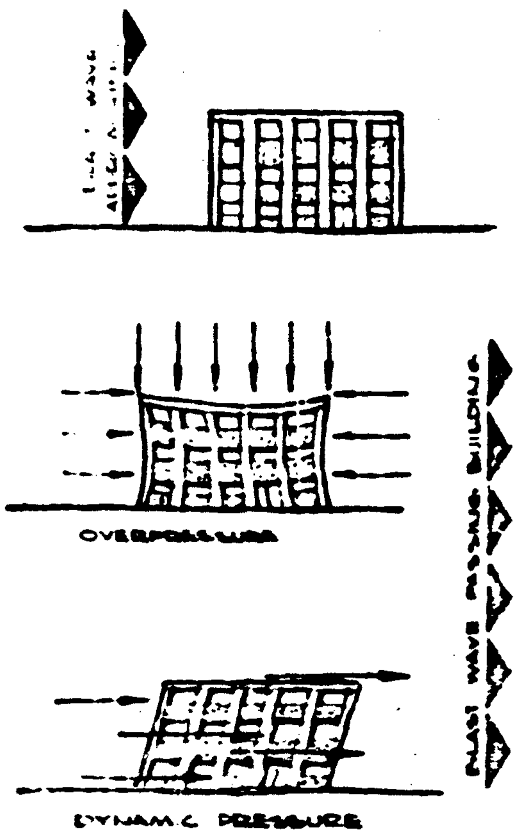
BLAST EFFECTS

The most damaging effects to buildings from a structural standpoint are caused by the blast effects accompanying the detonation of a nuclear weapon. In considering the destructive effect of the blast wave, the two most important characteristics are (1) the overpressure, i.e., the excess over atmospheric pressure caused by the compression of the air within the blast wave, and (2) the dynamic pressure, (the wind pressure caused by the motion of the air particles within the blast wave). Most conventional structures will be damaged to some extent when the overpressure in the blast wave is approximately one pound per square inch—the pressure at which glass windows will usually shatter with an occasional window frame failure.

It is pertinent to call attention to the fact that the above pressures and those to be discussed later are all in terms of pounds per square inch (psi), where one psi is equivalent to 144 pounds per square foot (psf). Inasmuch as conventional wind load design is for approximately 50 pounds per square foot and design floor loads are on the order of only 80 to 100 pounds per square foot, the importance of the pressures encountered in the blast wave of a nuclear explosion is immediately evident.

As the blast wave advances away from the center of explosion, the overpressure at the front steadily decreases due to the increased volume and the pressure behind the

shock front falls off. This overpressure, which is caused by the compression of the air within the blast wave, acts equally in all directions and thus tends to compress or squeeze any object engulfed by the blast wave. The dynamic pressure, which is caused by the motion of the air particles within the blast wave, acts in direction of the movement of the blast wave and thus tends to push or drag any engulfed object.



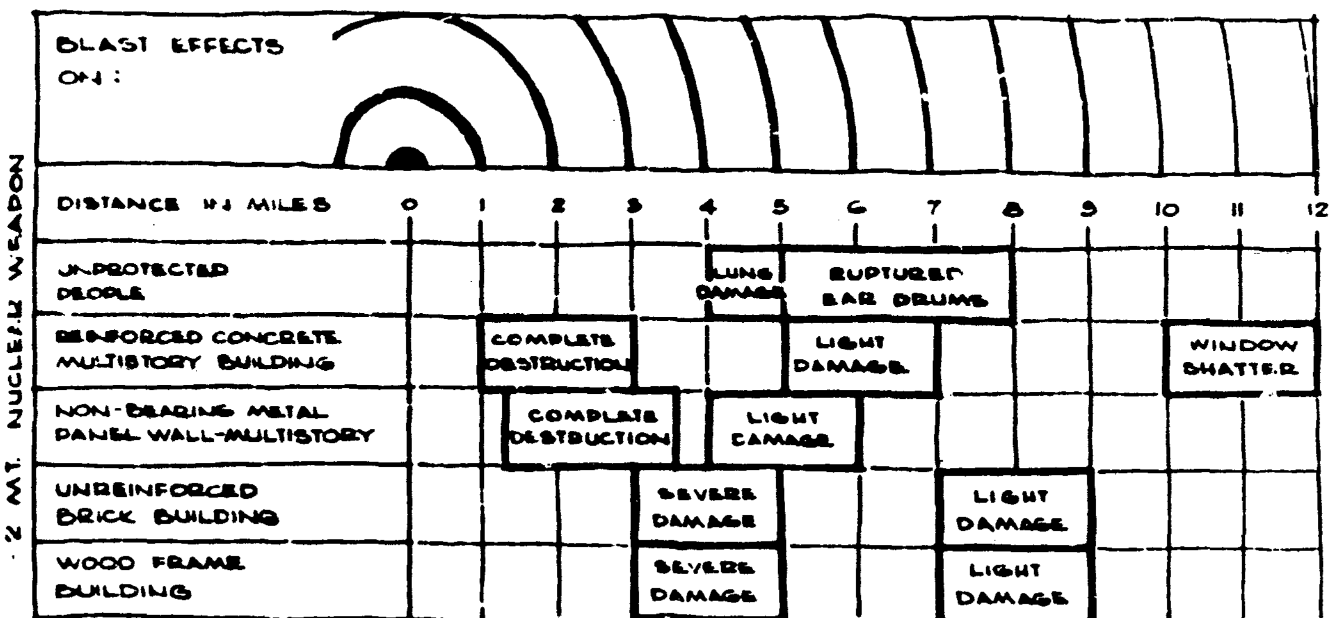
The difference in the air pressures outside and inside the building produces a force causing possible damage. After the blast wave has completely engulfed the building, not only will the building walls and roof experience this force, but also the frame of the building will be subjected to a drag force caused by the dynamic pressure. Thus when the blast wave encounters a building, there is at first a buildup of pressure on the front face. This is followed by a gradual unloading of the front face as the blast wave progresses past the structure, loading as it does so the roof and sides and lastly the back face.

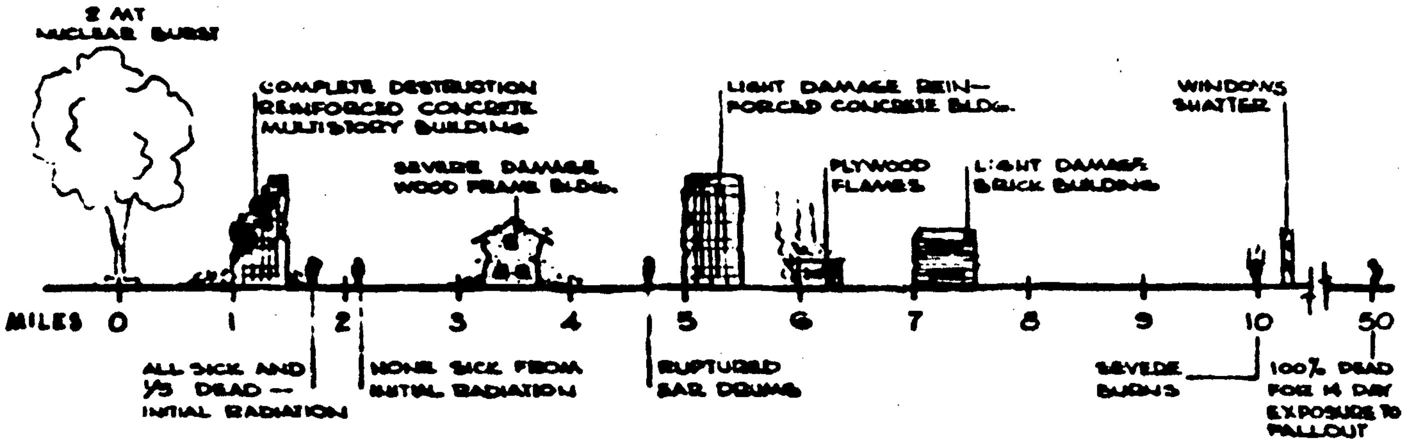
The structural damage sustained by a building will depend on the relationship of the loading to the structural strength and rigidity. This structural strength and rigidity will in turn depend upon the basic structural system, materials of construction, sizing of individual elements, connection details, etc. The blast loading will depend upon the size and location of the nuclear weapon detonation, the building size, shape, and position.

In addition to the structural system of a building, the blast wave can also inflict damage on exposed items such as utility lines and connections to the building and

mechanical equipment installed outside the buildings. To prevent damage to people, material, and other items inside a building it is necessary to provide some positive method of excluding the blast from entering the interior of buildings.

Damage to structures and people is illustrated below, using a typical 2 MT nuclear weapon as an example.





SUMMARY

The relationship of distances with the various effects of a 2MT nuclear weapon is included in the summary sketch above. It should be noted that the various effects on persons are illustrated for positions with the person in an unprotected position. It is interesting to note the ranges at which blast, initial radiation, thermal radiation, and fallout are significant. From this summary can be seen that the potential area of damage from blast and initial nuclear radiation is relatively small compared with the potential area of damage from fallout radiation.

CHAPTER THREE — SHELTER PLANNING

SHELTER NEEDS

Before discussing the various aspects of shelter planning, (shelter needs and architectural planning considerations), it might be well to briefly discuss the necessity for shelter.

The weapons effects discussed in Chapter Two are such as to require people within the damaging range of an explosion to be afforded some degree of protection. The effect with the greatest damaging radius and longest duration is that of radioactive fallout and is such as to require in most instances the provision of a protective enclosure within an existing building, cave, tunnel, etc. Inasmuch as the fallout radiation may be of such magnitude to require protection for a period of several days, consideration must immediately be given to the provision of a satisfactory environment in which people can live for the duration of the outside danger.

To provide this protected and suitable environment requires consideration of the human needs — air, food, water, sanitation, light, color, sound, etc., and the shelter requirements for the functions of living, sleeping, feeding, recreation, and necessary support. After considering these human needs and shelter requirements, one can then proceed to the architectural planning considerations involved in shelter planning, the radiation shielding, the structural, the mechanical, and lastly the planning for shelters.

HUMAN NEEDS FOR SHELTER OCCUPANCY

Air

Air must have specific characteristics and must be provided in sufficient quantities in order to be satisfactory for shelter occupancy. Factors which must be considered in the shelter habitability problem are: carbon dioxide and oxygen content; carbon monoxide content; humidity, temperature and air movement; CBR contaminants; and odor.

Carbon Dioxide Build Up — Oxygen Depletion

Generally, within a closed space, the build up of carbon dioxide will incapacitate an individual before an oxygen deficiency can occur. Criteria established by the U.S. Navy for submarine occupancy,[1] limit the carbon dioxide concentration to 3.0% by volume. This limitation is applicable for short intervals only. For longer periods of occupancy, the maximum allowable carbon dioxide content is lower.

The time required for carbon dioxide content to build up to 3% is given by:

$$T = 0.04 \frac{V}{N}$$

Where
T = Time (hours)
V = Net volume of space (cu. ft.)
N = Number of occupants

Carbon Monoxide

With proper precautions carbon monoxide (CO) is not a factor of concern. However, if even a small quantity of this gas is permitted in a closed space it will result in a dangerous condition. A concentration of as little as 0.5% CO in air can cause death after one hour. Even 0.1% concentration will produce well defined symptoms. 2

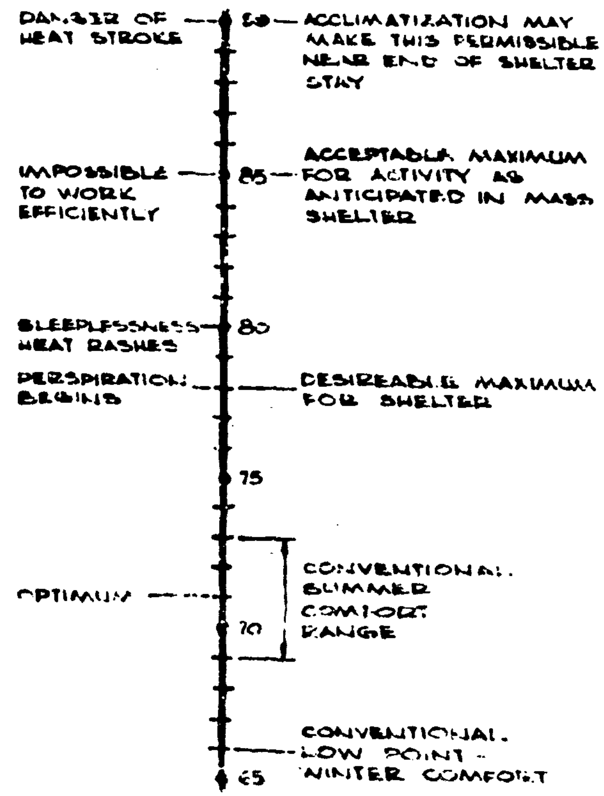
Dangerous levels of CO are caused by various sources. The most common source of CO is produced by the exhaust from a gasoline engine. Excessive CO quantities may also be produced by:

Fumes from ordinary fires	3% CO
Coal gas	6% CO
HE Bomb	60% to 70% CO

Humidity, Temperature and Air Movement

A single measuring index, that of effective temperature (ET), is commonly used to denote the combined effects of humidity and temperature, with air movement kept constant. Properly controlled air movement is desirable.

The chart developed from values of the ASHAE Guide 3 can be used to determine ET limits for shelter comfort. It is generally necessary to provide cooling in a mass shelter in order to keep the ET within tolerance limits. Ventilation may provide sufficient cooling, but under extreme external conditions, air conditioning is required.[4]



EFFECTIVE TEMPERATURE SCALE

CBR Contaminants

Among the most critical needs for shelter environment is the restriction of chemical, biological, and radiological contaminants. The tolerance limits vary with the specific contaminants but in all cases these limits are extremely low.

Odor

Odor control is of minor importance as a human need, because of the adaptation of the olfactory sense.

The above needs for air are so interrelated that it is difficult to consider any one of them without involving the others. Proper attention to ventilation will solve many of the problems which exist in connection with air composition, temperature, humidity, air movement, pollution, and odors. The manner by which adequate ventilation is supplied will be covered in detail later in this chapter.

Food

Humans can survive with little or no food intake for periods beyond the anticipated for shelter stay. However, the problem is not simply to keep the sheltered alive, but to enable them to perform recovery tasks after leaving the shelter. In the event of any disaster, food and water are not only necessities from the standpoint of physiological needs but also may tend to reduce fear and tension. Serving familiar foods prepared in familiar ways may further help to reduce anxieties. Along with providing fresh air to breathe and radiation shielding, food and drink are the most important requirements for survival.

Nutritional Levels

Many authorities [5] state that a minimum of 2000 calories per day plus a supplement of vitamins is necessary to sustain the average young male. This insures that there is a minimum weight loss and no deterioration in health. Many of the diets recommended for shelter life are based upon this level. "As little as 580 calories of carbohydrate with 4.5 grams of salt and a vitamin supplement will maintain the capacity for work for 12 days. Doubling the amount of calories will maintain capacity for work for 24 days without deterioration of pulmonary ventilation, oxygen depletion, and pulse rate responses. If weight loss does not exceed 10% during this time, performance capacity is well maintained." [6]

It is thus apparent that a diet ranging from 1500 to 2000 calories per day is more than adequate for emergency shelter life.

Water

Survival in a shelter is dependent on an adequate supply of water. Generally, it will be necessary to provide both potable and non-potable water in order that the human and mechanical functions within the shelter may continue without interruption. Potable water will be needed to sustain life, for food preparation, and to satisfy limited medical facilities. Water, which can be non-potable, may be

needed for personal hygiene, sanitation systems, decontamination systems, engine cooling, air conditioning, and fire fighting equipment.

The quantity of potable water required will depend upon the activities of the persons involved as well as the type of food consumed, and the temperature and humidity conditions within the shelter space. Survivors of a disaster have lived for ten to twelve days with as little as two to three ounces of water per day without causing any apparent bodily damage.[7] A more realistic figure for minimum requirements of potable water in a typical shelter is four to six ounces per person per day. This amount will suffice only if the effective temperature is at a satisfactory level and if sufficient food is available. A quantity of one-half gallon to one gallon per person per day of potable water should provide a reasonable degree of comfort, and permit limited quantities for personal cleanliness.

In a shelter with a primitive sanitation system, no air conditioning system, and with no provision for decontamination there is no need for non-potable water. The amount of non-potable water that will be needed will depend upon the equipment involved in each individual case.

Sanitation

The shelter sanitation needs are of lesser importance than the needs of air, water, and food. This is not to be construed as an excuse for ignoring sanitation problems, but rather a recognition of priority of needs.

Needs for sanitation in a shelter are related to the following items: disposal of dry rubbish, wet garbage, human wastes, and waste water from machinery; prevention of unpleasant odors, sounds and sights; and disease.

Light

Light is desirable in order: (1) to maintain law, order, and security; (2) to permit circulation; (3) to permit shelterees to take part in recreation activities; and (4) for personal hygiene.

Darkness is desirable for: (1) maintaining a daily life cycle; and (2) providing privacy.

Long periods of inactivity tend to increase tension and discontent; consequently the activity involved in the daily life cycle will be of value in reducing these tensions. The stimulation of varying lighting conditions will aid in keeping human senses alert. Some form of cyclic control of light should be established within the shelter.

Color

Color plays an important role, not only in relation to the psychological aspects involved in planning but also as an aid in lighting the shelter. The colors chosen will have a great deal of bearing upon whether the lighting is successful or not.

It is important that not only physical but also psychological factors be considered in planning color schemes for shelter interiors.[8] The appropriate use of color in the shelter may aid in sustaining emotional stability.

Sound

Sound may influence the performance of tasks other than hearing and may contribute to feelings such as boredom, fatigue, or relaxation. Any increase in noise level above threshold tends to increase muscular tension and consequently increase expenditure of energy. This would be particularly undesirable in the shelter situation. For muscular performance tasks not requiring fine coordination and precision, noise apparently has little adverse effect, even for extremely high levels at short periods of time. It may in fact slightly improve performance for a brief time. However, fine muscular tasks requiring a high degree of coordination and precision, are adversely affected by noise. Prolonged exposure to the noise will gradually result in a degree of accomodation. The adverse effect of noise on mental activity increases as the task increases in complexity.

For effective shelter functioning a degree of acoustical privacy is needed; for instance noise from recreation should not interfere with sleeping. The fact that noise in the shelter could become detrimental is substantiated by experiment. In this experiemnt among seventeen objectionable items, noise was considered fourth in discomfort, exceeded only by seating discomfort, lack of space and restriction of water uses.[9]

SHELTER REQUIREMENTS

The human needs for shelter occupancy have been discussed above. It is now necessary to consider the shelter requirements in order to satisfy the needs of the persons in the shelter. Various requirements exist in order to satisfy the following: shelter living (sleeping, feeding, and recreational facilities); supporting functions (storage, space requirements for functional engineering systems, entrance and decontamination facilities, miscellaneous activities such as medical, communication, maintenance, etc.).

In order to put the various requirements into perspective it is necessary to briefly discuss operational aspects of a shelter. Depending upon the time of arrival of the fallout, entrance into the shelter may or may not be a critical operational item. Therefore, speed of movement of persons entering the shelter may or may not be of importance. If entry to the protected area is required after the arrival of the fallout it is necessary to enter through decontamination facilities where contaminated particles on the body and clothing can be removed. It may be necessary to control the entrance to a protected area for any of the following reasons: (a) to prevent exceeding the maximum capacity of the shelter; (b) to prevent direct entry of radioactive fallout; and (c) to prevent uncontrolled entry of persons requiring decontamination.

Space may be at a minimum in a shelter. The total amount available and its arrangement are critical factors in determining the shelter living conditions. Extremely restricted shelter space will limit the types of activity and the extent to which they may be pursued. It may restrict comfort, cause claustrophobia, increase social conflicts, increase the spread of disease and cause emotional upset. Inasmuch as it is necessary for the shelter occupants to remain within the protected area for an extended period of time (days) it is important to create an adequate living environment.

Because of general restrictions of space within this area multiple usage for living, sleeping, recreation, etc. may be required. Therefore, multiple usage of space as well as the provision for a satisfactory internal environment requires spacial planning considerations, including adequate space for the various functional engineering systems.

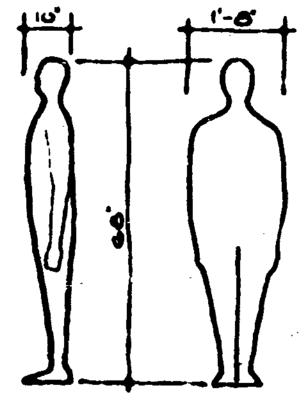
Shelter Living

Generally any type or size of space might be usedful for shelter living functions —sleeping, feeding and recreation.

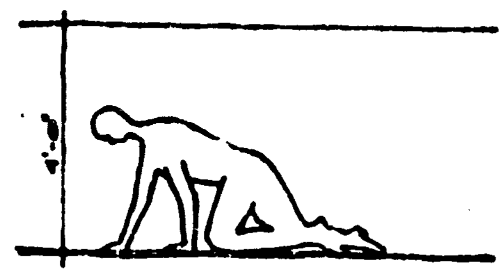
The degree of comfort and efficiency of these spaces depend upon the specific characteristics of the spaces such as ceiling height, division of areas, privacy, circulation, bunking and eating arrangement, etc. Since the planner is concerned with activities identical to day-to-day living, it might appear logical to use conventional criteria. However, the basic philosophy of shelter is that of protecting as many persons as possible within a given space. It is therefore necessary to establish emergency criteria.

Inasmuch as shelter is being designed for human occupancy, it is logical to use the dimensions of the average adult as a basis for planning criteria—height, 5 feet 8 inches, and width, 20 inches.

A minimum ceiling height of 4 feet is recommended.10 Under these restricted conditions, standing is impossible while sitting on the floor is possible but not desirable. A space with these characteristics should not be considered for a long-term occupancy. However, in specific cases such spaces may be used for temporary high protection quarters. If the ceiling height is four or five feet the movement



AVERAGE ADULT MALE



MINIMUM CEILING HEIGHT

is greatly restricted, hence only a limited capacity is feasible.

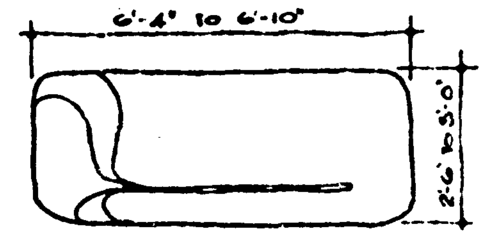
For unrestricted movement within the shelter area it is necessary to establish floor to ceiling height based on the height of an average man (5 feet 8 inches). This is a theoretical figure of little practical application. In any building the ceiling height should not be lower than 7 feet 6 inches . Conventional ceiling heights vary with the building function and the room area. For the purpose of developing shelter configurations for Navy buildings a nominal ceiling height of 9 feet has been used in this guidebook.

Sleeping

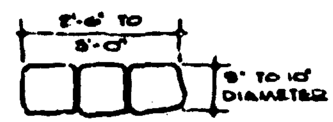
The use of bed rolls would be required in a space with 4 foot ceiling height. Each person would need only the space necessary for his bed roll. An average size bed roll of 2 feet 6 inches by 6 feet 6 inches, requires an area of sixteen and one quarter square feet.

To allow a person to sit comfortably on a bunk, a ceiling height of 58 inches plus a clearance of approximately 2 inches, totaling 60 inches (5 feet) would be required. The floor space required would be no different that that of the 4 foot high shelter. However, the volume would increase and the psychological problem of being in a tight quarter probably would be somewhat reduced. Movement would still be restricted.

Since the average adult male is 20 inches wide, the minimum bunk width should be 25 inches, allowing 5 inches

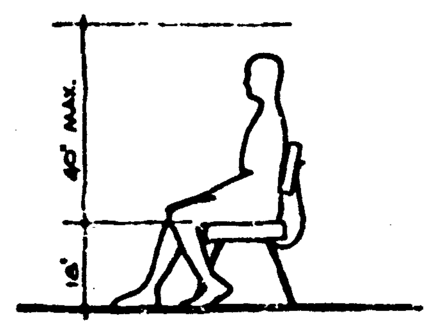


BAG UNROLLED



BAG ROLLED

SLEEPING BAG

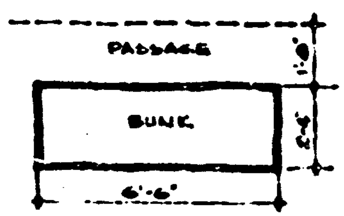


SEATING HEIGHT REQUIREMENTS

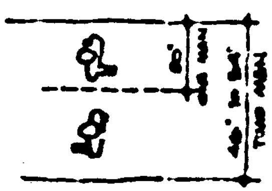
BUNK LENGTH (IN)	BUNK WIDTH (IN)	CLEAR SPACE ABOVE BUNK (INCHES)	FLOOR AREA OF BUNK (SQ FT)	SOURCE
78	28	20	15.2	[illegible]
78	28	40	15.2	[illegible]
74	25	20	12.8	SUB CREW BERTHING [illegible]

VARIOUS BUNK SPACE REQUIREMENTS

ACCEPTABLE
BUNK
CLEARANCES



PASSAGEWAY
REQUIREMENTS



for comfort. The above figure conforms to the standars used for crew berthing on board submarines. This same standard for bunking should be applied since the persons being sheltered may perform recovery and other post attack functions.

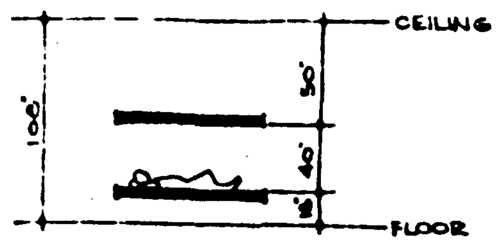
Since space is at a premium, it appears logical to use 20 inches as a lower limit for passage between bunks. A passage on one side of a bunk only, requires a floor area of 26 square feet for both bunk and passage. Three separate stack arrangements may be considered using a nine foot ceiling height, while allowing for seating and providing a maximum number of bunks:

(1) If a double bunk arrangement is used, the bottom bunk should be 18 inches above the floor and there should be a 40 inch clearance between bunks in order to facilitate seating. If considering the net bunk area only (2 feet 1 inch by 6 feet 2 inches), this stack arrangement requires six and one-half square feet per person. This double bunk arrangement permits seating on both bunks.

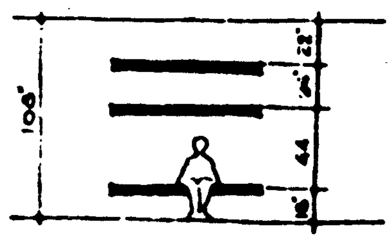
(2) If there is to be seating on the bottom bunk only, it is possible to provide for a triple bunk within the same area. This stack then requires four and one third square feet per person.

(3) It is possible to use a four bunk stack and still provide seating on the lower bunk by inserting a demountable fourth bunk between the existing first and second bunk. This stack requires three and one quarter square feet per person. Such an arrangement requires lowering the lower bunk 2 inches.

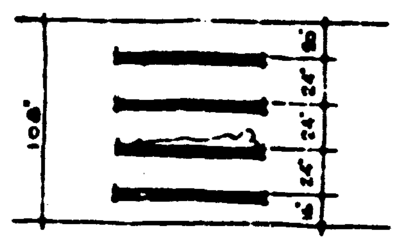
A high ceiling may provide the possibility of more bunks in the stack. However, circulation difficulties might be



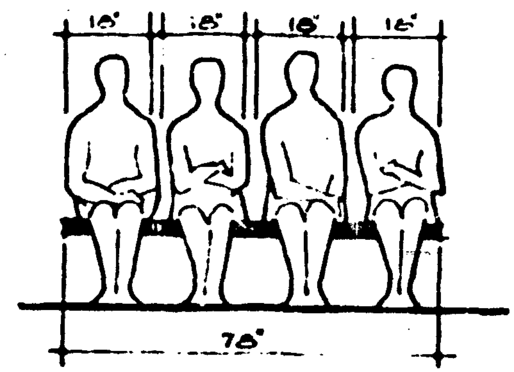
① DOUBLE BUNKS: 15 SQ.FT./PERSON



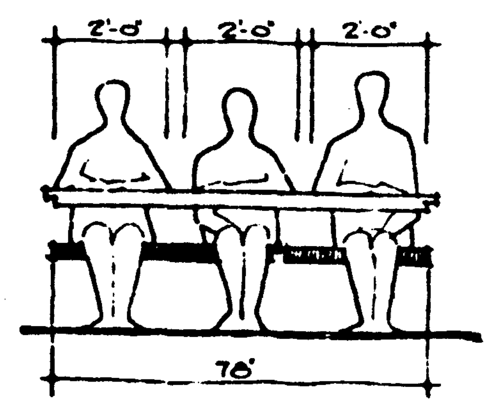
② TRIPLE BUNKS: 9 SQ.FT./PERSON



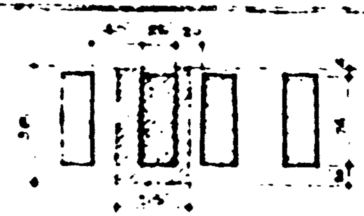
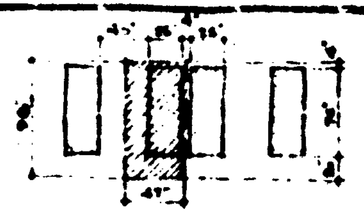
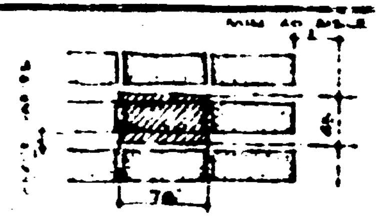
③ FOUR BUNKS: 6½ SQ.FT./PERSON



FOR SEATING



FOR EATING

PLAN OF BUNK LAYOUT		SPACE PER PERSON — VERTICAL BUNK ARRANGEMENT: 1 BUNK	2 BUNKS	3 BUNKS	4 BUNKS	COMMENTS
	SQ FT PER PERSON	37	18½	12⅓	9¼	ACCESS PROVIDED FROM THREE SIDES. ALLOWS PEOPLE TO PASS EACH OTHER AND ALLOWS MOVING OF CARTS, ETC.
	CU FT PER PERSON	333	166	111	83	
	SQ FT PER PERSON	30⅔	15¼	10⅔	7¾	ACCESS TO EACH BUNK FROM THREE SIDES BUT PASSAGE BETWEEN BUNKS LIMITED TO ONE PERSON AT A TIME.
	CU FT PER PERSON	278	139	92⅔	69½	
	SQ FT PER PERSON	32	16	10⅔	8	ACCESS TO BUNKS FROM TWO SIDES ONLY. DISTANCE BETWEEN PAIRS OF BUNKS ALLOW PASSAGE OF PEOPLE AND CARTS. PRIVACY CAN BE OBTAINED BY FIXED OR MOVABLE PARTITIONS BETWEEN
	CU FT PER PERSON	288	144	96	72	
	SQ FT PER PERSON	24½	12¼	8	6	ACCESS TO BUNKS FROM TWO SIDES. AISLE WIDTH BETWEEN BUNK ROWS INCREASE WITH INCREASED LENGTH OF ROWS. (MAX. WIDTH APPROXIMATELY 40")
	CU FT PER PERSON	220	110	75½	55	

encountered by an increase of the number of bunks.

It is possible to provide for seating of four persons only on the lower bunk. If there is no specific dining space and the shelterees are required to eat at their bunks, the seating on the lower bunk would be restricted to three persons. It is possible for persons to be seated opposite each other with the minimum established aisle width of 20 inches. However, 20 inches is an absolute minimum and more space is desirable. The space under the lowest bunk may be utilized for storage.

Many factors will incluence the arrangement of the bunks—the spaces available, the operation of the shelter, and the number of persons to be sheltered. The chart at left illustrates four possible bunk arrangements, and indicates a method of approach with associated values of space occupancy. There are many other configurations that might be applicable for specific cases.

Feeding

Arrangements for feeding—storage, preparation and distribution of food—might vary considerably from shelter to shelter depending upon the shelter diet. It is desirable to develop a relatively "primitive system" for feeding, thereby eliminating the need for a multitudinous array of gadgets and devices associated with the contemporary kitchen.

In a protected area it is desirable to use a minimum of space for storage purposes in order to maximize the shelter capacity. Because of external radiation conditions it is assumed that all of the food to be consumed during the shelter stay would be in a protected area to avoid exposure of personnel while transporting food from unprotected storage. (Food in closed containers will not be come contaminated in an unprotected area). Food to be stored should be of such a nature that (1) it occupies little space; (2) it requires no special storage processes, e.g., refrigeration; (3) it does not deteriorate in a stored condition; and (4) it has a minimum of discard material.

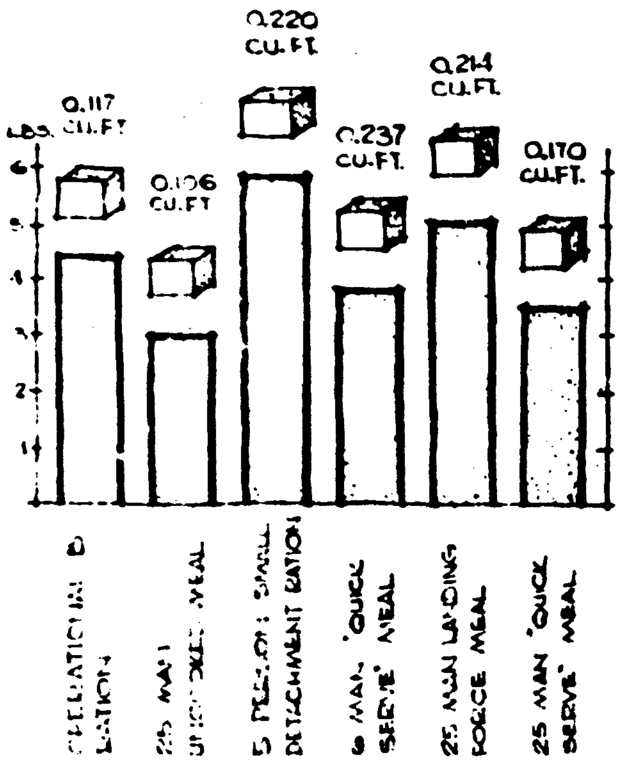
The preparation of certain foods would demand a complex system of equipment and supporting services. In order to minimize such items it is desirable to select food which can be prepared independent of mechanical and electrical facilities.

The serving of food in a shelter should require little or no equipment—utensils, dishes, dishwashing facilities, serving carts, etc.

Basically one might consider two general types of food: (1) conventional food, stored, prepared, and served in a conventional manner; and (2) foods which, because of their unique nature, lend themselves to shelter use. The second category, including military food packs and other types of quick-served and unitized meals, lends itself well for shelter use. Conventional food, which is applicable for use in specific types of buildings, (home shelter, restaurant shelter, etc. will not be discussed further.

Military food packs

Both the C ration and 5-in-1 rations are sufficiently stable for shelter storage. They are packed in very small cans



WEIGHT CUBE COMPARISONS OF CURRENT AND FUTURE RATIONS"
(DATA FIGURED ON A PER RATION BASIS)

with 3 or 4 cans required per meal for one person. The amount of discard material may be excessive and become a drawback to their use. The B ration is packed in larger containers, with some of the items requiring cooking facilities. The A ration is much less suitable since it includes many items which are perishable.

Experimental Diet

Several experimental diets and methods of food preparation for shelter use are being developed. [11] These are based on two feeding concepts—the quick-serve meals and the unitized, uncooked meals. The quick-serve meals consist of precooked dehydrated food items. Only water has to be added for the preparation of these meals. A variety of 21 quick-serve meals are under development. The unitized, uncooked meals will be similar to the quick-serve meals, but they will be packaged in 25 man units. Neither of these two types require refrigeration.

The chart illustrates space requirements for various diets. The feeding system will effect the planning and organization of the shelter space. To optimize shelter capacity it is logical to eliminate single use space such as an area used for feeding only. Therefore, the alternatives are (1) eating in the bunk without changing the configuration, or (2) converting a portion of the bunk area into a temporary eating space. Other factors to be considered are the control and distribution of the food. For example, if each person is responsible for the control of his own food supply individual storage must be provided in the bunk area or in a common storage area. The method of distribution of food could effect the aisle width and create circulation problems.

Many problems associated with the feeding system are matters of command nature, e.g., security of food storage and excessive and uncontrolled individual rate of consumption.

Recreation

Considering the extended time involved in shelter stay some provision should be made for recreation facilities. Storage may be needed for such items as cards, chess, checkers, supply of books, motion picture equipment, films, phonographs, records, and devices for exercise. Depending upon the shelter operation it may be necessary to provide privacy between an area used for recreational activities and sleeping areas. Much of the privacy might be achieved through initial judicious selection of spaces to be used for shelter. Temporary arrangements within the shelter space might also satisfy this privacy requirement.

Supporting Functions

Functions supporting the three basic aspects of shelter living—sleeping, feeding, and recreation activities—may have specific requirements which must be considered in shelter planning.

Storage requirements for food have been included above. There are many other items which, if included in the shelter, will require storage space. The specific amount of space required will depend upon the operation of the shelter and the shelter type. Items which might be included are: blankets, clothing, (for distribution in the event of a person's entry into the shelter after exposure to fallout), towels, (for decontamination shower), tools, (hammers, saws, wrenches, etc., needed in the event of repairs to the shelter or modification of the shelter space itself) and spare parts.

Depending upon the bunk arrangement and the type of bunks used, storage space for disassembled bunks may be required. The storage space left empty by the removal of these bunks during shelter use may be converted for storage of personal items.

Space requirements for functional engineering systems are discussed in detail under the section, Mechanical Planning Aspects in this chapter. They are not included in this part because they are considered closely related to the convertible shelter planning and they should not be discussed independently of such planning considerations.

Because of the crowded conditions existing within a shelter, certain medical facilities may be needed. Isolation and storage space for drugs and medical equipment may be necessary, depending upon the operational plan with regard to shelter occupancy. The isolation of spaces can range from completely separated rooms within the protected area to a temporary screened section of the bunk area. Provisions for a mortuary is not considered necessary for a military shelter. However, large air tight plastic bags might be included to serve this purpose. Any dead could be disposed of by removal from the protected area at such time as external radiation levels permit.

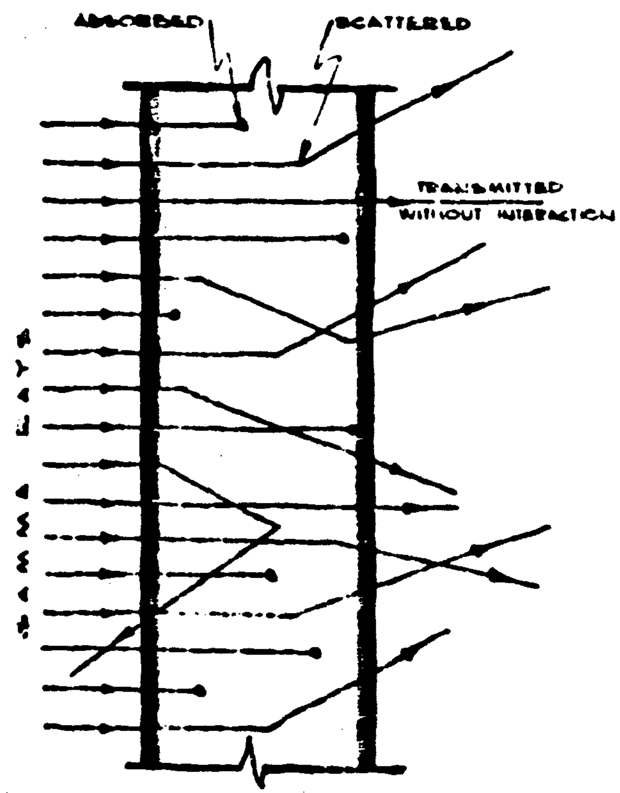
Communications may be necessary for shelter operations. However, unless a shelter has an operation mission such as a communications activity it has little affect on the planning aspects of shelter. Certain communication systems may require supplementary power and are discussed in relation to mechanical systems.

SHIELDING

The Nature of Gamma Radiation

It may be helpful to compare gamma rays with light inasmuch as they have much in common. Both are forms of electromagnetic energy. Both propogate as bundles of energy called photons. A gamma ray photon, however, has about a million times the energy of a light photon. Both travel with the speed of light, 186,000 miles per second. Both are emitted isotropically, (equally in all directions from a point source) and travel in straight lines essentially unaffected by gravitational, electrical, or magnetic forces. The gamma rays are attenuated by distance from a point source in an inverse square way as are light rays. Both are absorbed by matter. In their absorption, however, they differ most markedly. Whereas relatively few substances are transparent to light, all substances are more or less transparent to gamma rays. Perhaps a more accurate word than transparent is translucent since all substances will absorb gamma rays to some extent but even the largest amount of any substance will not be absolutely opaque to gamma rays.

The life history of the average gamma ray is very brief. It is born as a radioactive nucleus decreases its internal energy. The gamma ray travels in a straight line like a bullet until striking an atom, which may absorb it or scatter it. If scattered, it travels in another straight line in a different direction with decreased energy until it encounters



TRANSMISSION, ABSORPTION, AND SCATTERING OF GAMMA RAYS IN MATTER

another atom which again either absorbs it or scatters it, and so on until it is absorbed and dies. This entire life history usually requires less than a millionth of a second.

If eyes were sensitive to gamma ray photons as they are sensitive to ordinary light photons, a wall might appear to be a gray translucent substance when you viewed the gamma ray sources through it. Increasing the thickness of the wall would seem to darken its "grayness". Adding more and more mass would make the wall appear darker and darker, but never completely black; it would always be possible to see the gamma sources, eventually only as faint glimmers, but always visible. Some gamma rays will penetrate the thickest of walls.

There is a popular misconception about the nature of gamma rays that likens them to viruses that float around in the air ready to infect people with "radiation sickness". Nothing could be further from the truth. When a radioactive source is removed from a room the gamma rays it had emitted are gone essentially instantaneously; just as when an electric light bulb is turned off the photons it had been emitting are gone essentially instantaneously. Furthermore, there is no residue, that is, no radioactivity to indicate that the gamma rays were ever there.

It is not true that "gamma rays produce radioactivity" any more than it is true that light produces flashlights, or that radio waves produce transmitters. A person with radiation sickness can not infect others: any more than a person with sunburn can infect others with sunbrun—sunburn is, indeed, a form of radiation sickness.

<u>Protection Factor and Reduction Factor</u>

The term protection factor is a measure of the reduction in the amount of gamma radiation that would be received by a person in a protected location as compared to the amount he would receive in an unprotected position.

The protection factor, P_f, at a point within a building, is expressed by the ratio:

$$P_f = \frac{D_o}{D}$$

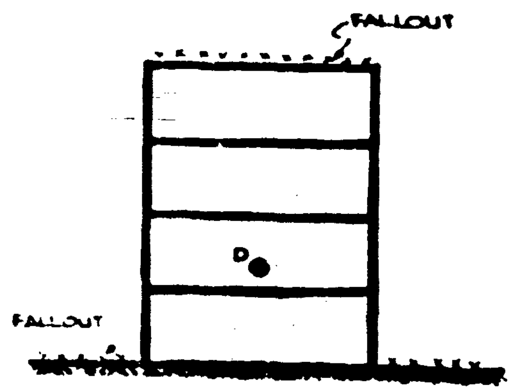
where D is the dose rate at the point within the building and D_o is the dose rate at the "standard unprotected position".

The standard unprotected position is a location three feet above a hypothetical smooth infinite plane covered with fallout. There are several reasons for the choice of this location for the standard: it gives an extreme, but not unrealistic, estimate of the dose to which the centroid of the body is exposed in an open contaminated field; and the reference intensity can be calculated to an accuracy of 2 to 3 per cent.

The protection factor on the first or second floor of a light frame residence will probably be about 1 to 3. The basement of the same building may have a P_f as high as 50 if it has no exposed walls. Sub-basements of fire-resistive multistory buildings often have protection factors as high as 100 or even greater.

The protection factor is a number equal to or greater than one. The reciprocal of the protection factor is usually

STANDARD UNPROTECTED POSITION



TYPICAL PROTECTED POSITION

determined in the shielding analysis of structures; it is called the reduction factor.

$$R_f = \frac{D}{D_o}$$

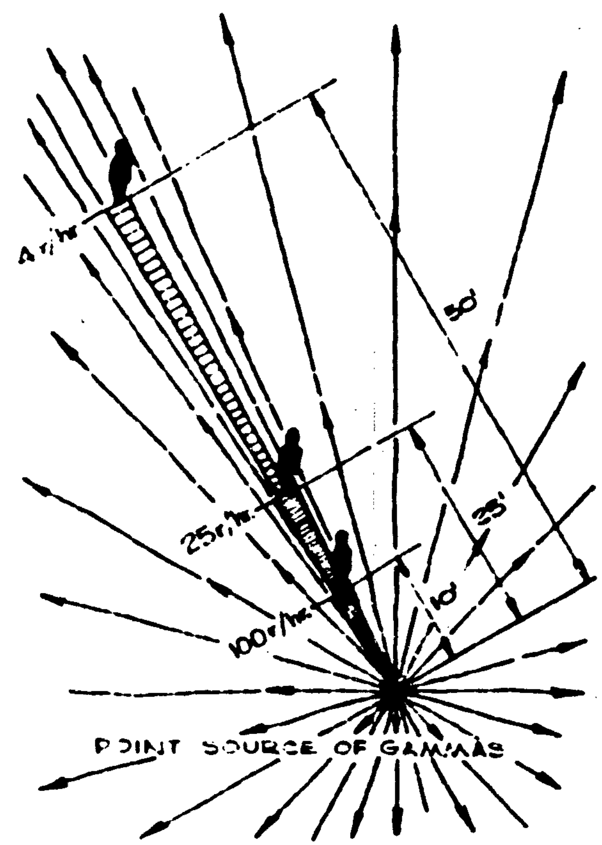
Reduction factors can be added when combining the effects of fallout on the ground and roof of a structure. For example, if the reduction factor from fallout on the ground is 0.02 and the reduction factor from fallout on the roof is 0.03 then the total reduction factor is 0.05 [illegible] protection factor in this case would be the recipr[illegible] 0.05, or 20.

Attenuation of Gamma Rays

Two effects determine the relative radiation dose reaching a detector point. They are the effect of distance and the effect of absorbing material between the source and the dose point. These two effects will be described separately in the following sections.

Distance Effects — Point Source

A fallout field consists of a vast number of point sources of radiation. The radiation received at any detector location in space is the sum of radiations coming from each of these point sources. Since fallout point sources emit radiation isotropically, the intensity of the radiation decreases equally in all directions with respect to the distance from the source. This is the same effect that is observed with a light bulb where the intensity of the light decreases with the distance from the bulb.



GAMMA DOSE RATE REDUCTION FROM A POINT SOURCE DUE TO DISTANCE

The radiation intensity, (dose rate), decreases as the square of the distance from a point source in a vacuum. If the dose rate 10 feet from the point source is 100 r/hr, then 20 feet from the source it will be one fourth as much, or 25 r/hr. Fifty feet from the source the dose rate will be 4 r/hr.

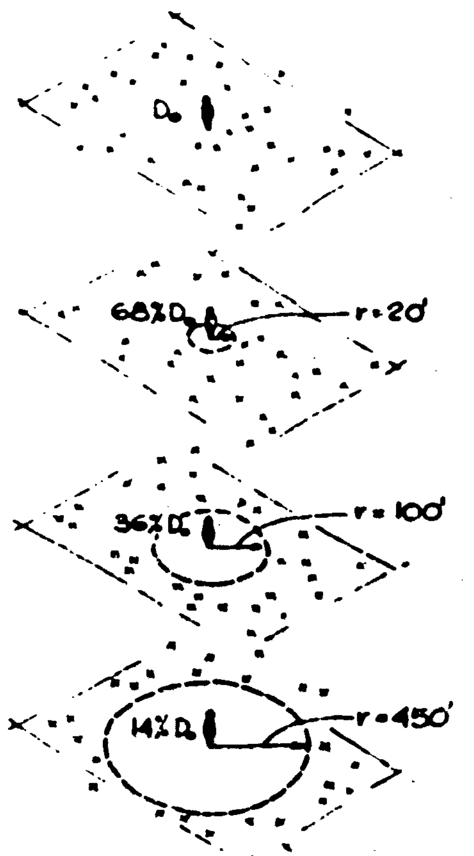
If the point source is in air rather than in a vacuum, there will be an additional slight decrease in the gamma intensity due to the mass of the air in addition to the purely geometrical inverse square decrease.

Distance Effects — Cleared Areas

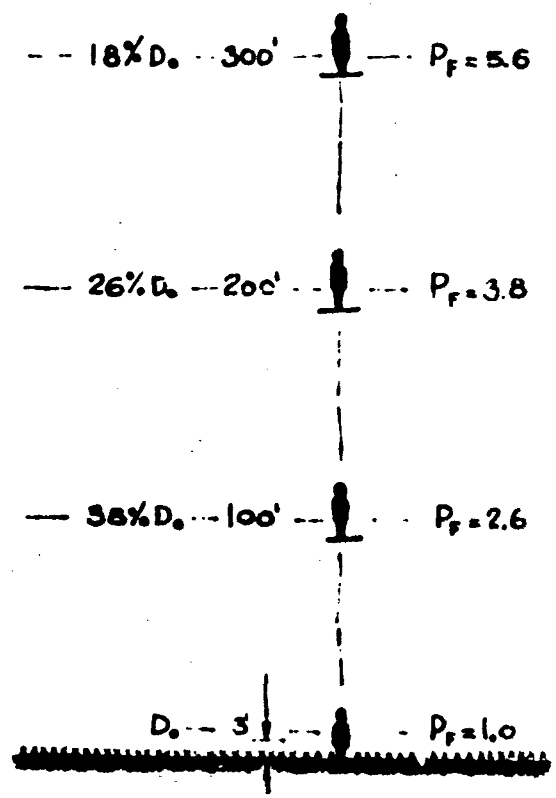
The dose rate within a cleared area in a fallout field is less than on the uncleared plane simply because the point sources of which the field is composed are further away so that the inverse square effect decreases the radiation intensity. The cleared area may be the natural result of a building occupying the space or may result from decontamination operations. In either case, a decrease in dose rate results.

If the dose rate three feet above an infinite uncleared flat plane of fallout is D_o roentgen per hour, it will be 68 percent of D_o at the center of a 20 foot radius circular clearing, 36 percent of D_o at the center of a 100 foot radius clearing, and 14 percent of D_o at the center of a 450 foot clearing.

These percentages refer to the dose rates at the centers of the cleared areas. At the edges of the areas the dose rates will be considerably greater. For example: the dose rate



GAMMA DOSE RATE AT THE CENTER OF A CIRCULAR CLEARING IN AN INFINITE PLANE OF FALLOUT



GAMMA DOSE RATE REDUCTION FROM AN INFINITE PLANE OF FALLOUT DUE TO HEIGHT

at the perimeter of the 450 foot radius area will be greater than 50 percent of D_o.

Mass Effects — Height above Fallout Plane

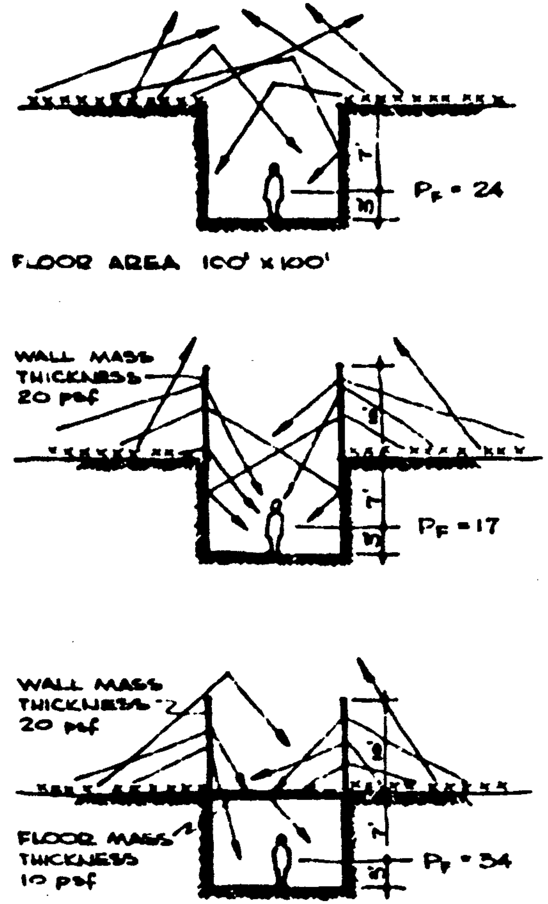
Dose rate decreases with height above a plane of fallout due to the shielding effect of the air mass. The more mass between the source and the point of interest the less the dose rate. Air has a density only 1/800 the density of water, so that considerable thickness of air is necessary before appreciable gamma attenuation is observed.

If the dose rate three feet above an infinite plane source of fallout is D_o roentgen per hour, then 100 feet above the plane it will be 38 percent of D_o, and 300 feet above the plane it will be 18 percent of D_o.

This decrease, which is really an air mass effect and not a distance effect, is the reason why one will often find better protection on the center floors of a tall building than on the lower floors. The upper floors usually offer poor protection because of radiation from fallout on the roof.

Mass Effects — Hole in the Ground

A considerable degree of protection is offered by any position that is out of the line of sight of direct radiation. By "line of sight of direct radiation" is meant of course line of sight as determined by "gamma rays sensitive eyes". Recall in this connection that all solids are transluscent,



HOLE IN THE GROUND

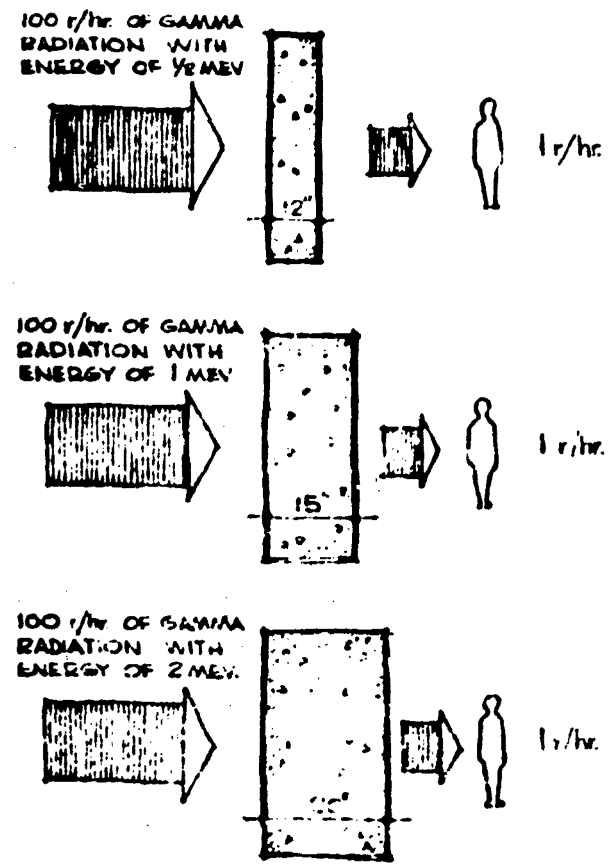
not opaque, to gamma rays. A thin wall, a steel curtain wall for example, is as transparent to gamma rays as a glass window is to light. An example of a location that is out of the line of sight of fallout gamma rays is a point at the bottom of a hole. There is so much soil between the sources and the detection point that practically all the radiation reaching the detection point consists of air scattered gamma rays.

The protection factor is 24 at a position 3 feet from the bottom of a rectangular hole in the ground 100 feet wide, 100 feet long and 10 feet deep surrounded by an infinite plane of fallout. (It is assumed that no fallout is in the hole)

Practically all the radiation that enters the hole has scattered in the air above the hole. If this hole in the ground were surrounded by a light vertical wall such as found in a frame house the protection factor would actually be reduced somewhat because of the scattering of additional gamma rays from the wall into the hole. However, even a light weight cover over the hole will have a pronounced effect on the protection factor. For example, a wooden floor of 10 psf would increase the protection factor to 34. Thus in a basement of a house of light walls and flooring, the dose received from ground radiation will usually be less than that received in a hole with the same dimensions as the basement.

Mass Effects — Energy Spectrum of Gamma Rays

Fallout gamma rays range in energy from about 0.5 to 2.5 million electron volts. (Million electron volts—Mev—is a measure of energy commonly used in nuclear physics.



RELATION OF THE PENETRATION POWER OF GAMMA RADIATION TO ITS ENERGY

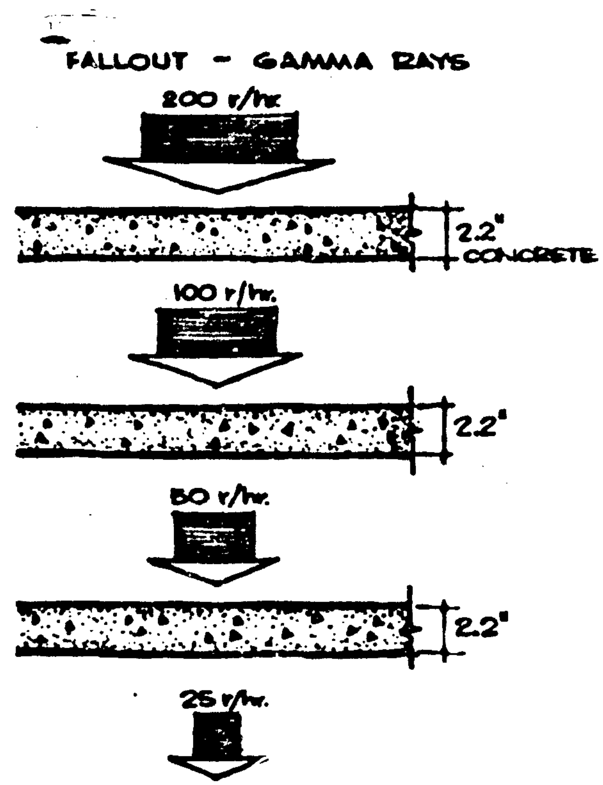
One Mev equals 1.6×10^{-13} watt-seconds. Thus the energy of 10,000,000,000,000 one Mev gamma rays would keep a 25 watt light bulb lit for less than a tenth of a second). The energy spectrum, i.e. the fraction of gammas having various energies, changes with time after the burst because many different radioactive spcies are contined in the fallout material, and each decays with its own characteristic half-life and gamma energy.

Because of this time variation it is necessary to make some decision regarding the choice of a spectrum to be used in shielding calculations. Fortunately the penetration properties of fallout gamma rays are not extremely sensitive to the choice of spectrum over the range of wall, floor, and roof thicknesses usually found in buildings. Thus it is often possible to make reasonably good estimates of protection factors by using one effective energy for the gammas instead of a spectrum of energies. An effective energy of 1 Mev will usually be conservative. Some of the more basic examples in this section use this effective energy; the shelter shielding examples, however, are based on the fallout spectrum that exists one hour after a nuclear burst.

Mass Effects — Mass Thickness

As gamma rays pass through matter some of them are absorbed and others are scattered and degraded in energy. Fewer will get through as the thickness and density of the material they are traversing increases.

The attenuation of a given shield, (a wall, a floor, or a roof) is related to its mass thickness which is its weight per unit area expressed in pounds per square foot (psf). A barrier of concrete, wood, earth, or steel with a mass



CONCEPT OF HALF-VALUE THICKNESS

thickness of about 27 psf will reduce fallout gamma rays intensity by a factor of about two. Twice the mass thickness, 54 psf, will reduce the gamma intensity by a factor of four; three times the thickness, 81 psf, will reduce the intensity a factor of 8, and so on. Each additional 27 psf decreases the intensity to about one-half its previous value.

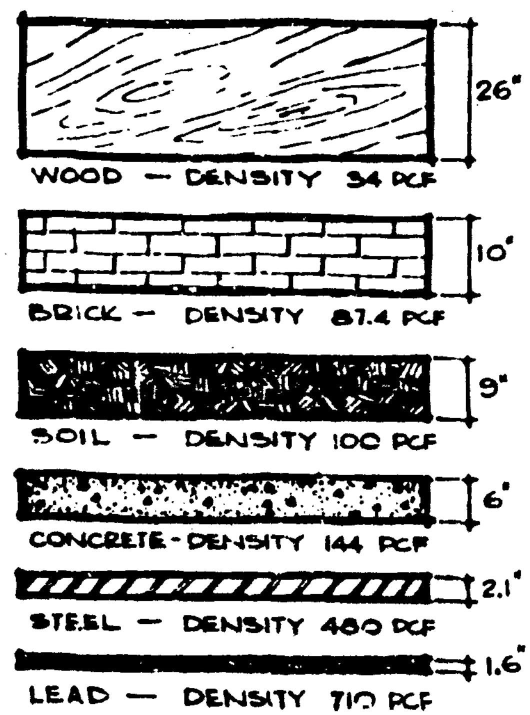
Mass Effects — Half-value Thickness

It requires 2.2 inches of concrete having a density of 144 pounds per cubic foot for a mass thickness of 26 psf to attenuate fallout gammas approximately by a factor of two. Thus 2.2 inches is the "half-value thickness" of concrete. Other approximate half-value thicknesses are listed in the table below both in inches and in psf. The important fact brought out by this table is that all common building materials have essentially the same half-value thickness when expressed in pounds per square foot. Thus it is the mass thickness of a barrier in psf that determines its shielding effectiveness, not its actual depth in inches, nor the material of which it is constructed.

Material	Density (lb/cu ft)	Half-Value Thickness (inches)	Half-Value Thickness (psf)
Steel	490	0.7	29
Concrete	144	2.2	26
Soil	100	3.3	27
Water	62.4	4.8	25
Wood	34	8.8	25

A more complete table of mass thicknesses for various types of roof, floor, and wall materials may be found in "Fallout Shelter Surveys: Guide for Architects and

EFFECT OF DENSITY



VARIOUS MATERIALS WITH EQUIVALENT 1 MEV GAMMA RAY ATTENUATION

Engineers", NP-10-2, Office of Civil and Defense Mobilization, Washington 25, D.C., May 1960.

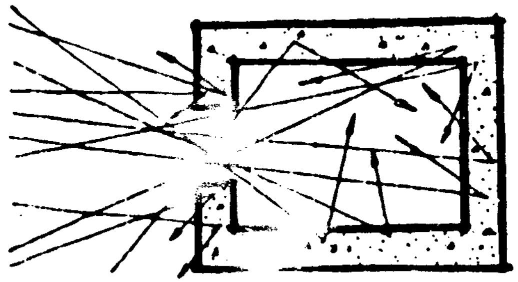
Mass Effects — Special Shielding Materials

There are no magical materials opaque to gamma rays, nor is it likely any will be discovered. The basic physical processes by which gamma rays may be attenuated have been well known for many years. Unless some new, totally unexpected, physical phenomenon arises, gamma shielding will continue to depend on MASS and DISTANCE. There are, however, some materials that may have limited use in special situations including:

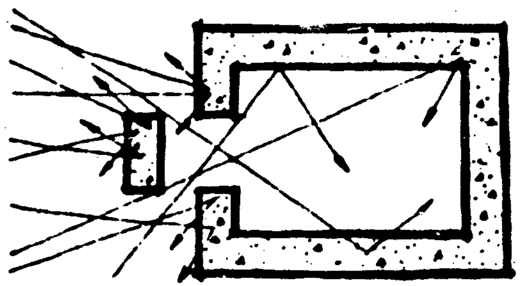
a. Heavy concretes, such as barite concrete with a density some 30 percent greater than ordinary concrete, may be used to reduce wall thicknesses in shelter spaces.
b. Lead glass may be used as window material. About 1.5 inches of lead glass is equivalent to 8 inches of concrete in the attenuation of fall-out gammas.

Mass Effects — Apertures in Shields

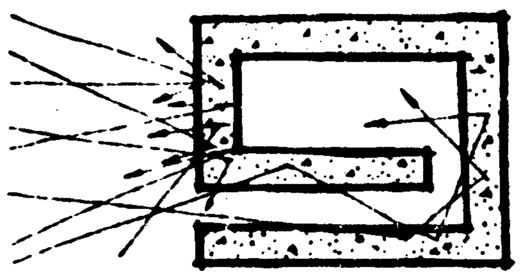
An aperture is any part of a gamma ray shield that has considerably less mass thickness than the rest of the shield. An opening is an aperture, as is a glass window or a light door in a heavy wall. The larger and lighter the aperture the more gamma rays it will admit. A small aperture, for instance, a six inch diameter ventilation duct, will admit very few gammas because few gammas will be traveling in exactly the right directions to enter



OPEN APERTURE



SHADOW SHIELD



INDIRECT ENTRANCE

GAMMA RAYS ENTERING APERTURE IN SHIELDED AREA (PLAN VIEWS)

the duct and pass through it. On the other hand, a large lightweight door can, unless properly placed or shielded, appreciably reduce the protection factor of an area.

An aperture that faces a flat horizontal surface on which fallout may be deposited is more dangerous than one that faces no potential radioactive sources. Thus high windows in an above ground shelter space will generally be better than low ones. Entranceways to interior shelter spaces that face the interior of the building or face heavy walls will usually be better than those that face exterior windows or exterior curtain walls.

The accompanying sketches indicate how entranceway design may be accomplished by the use of shadow shields or indirect entrances to reduce the number of gamma rays entering the shelter space. Some few may enter even a torturous indirect entrance by scattering off walls and other surfaces. In a correct entranceway design, however, the intensity of these gammas should be equal to or less than the intensity of the gammas coming directly through the walls, floor, and ceiling.

Shielding Examples

Building, shape, height, area, wall mass and percentage of apertures all affect the protection provided by a structure against gamma radiation. The effect on the protection factor of each of these variables is considered quantitatively in the examples below.

All of the examples begin with the reference building shape as shown on the right and each of the shielding variables is considered separately. The reference building shape has an area of 10,000 square feet and is 10 feet high (floor to top of roof slab). The walls and roof have 100 pounds per square foot mass thicknesses; this is equivalent to 8 inches of reinforced concrete. The reference building has no apertures (however the effect of apertures is shown in example 5).

All protection factors are calculated for points 3 feet above floor surfaces. The location of the point of interest is indicated in the sketches as a cross within a circle (⊕). Protection factors were calculated using procedures in the OCDM Engineering Manual Design and Review of Structures for Protection from Fallout Gamma Radiation, "Revised Preliminary Edition, December 1, 1960. These calculations take into account the four ways in which gamma radiation may reach the detection point: (1) direct radiation from the roof, (2) direct radiation from the ground, (3) radiation scattered in the walls and roof, and (4) radiation scattered by the air outside the building (sky shine).

The following symbols are used in the examples to designate mass thickness (units of pounds per square foot).

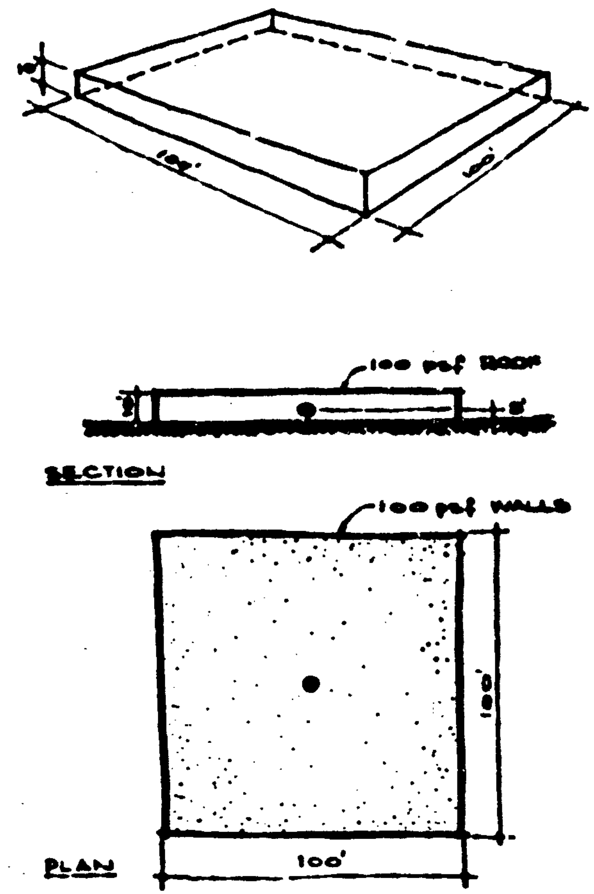
X_o total overhead mass thickness

X_o' overhead mass thickness of one element

X_e exterior wall mass thickness

X_i interior partition mass thickness

X_m middle partition mass thickness

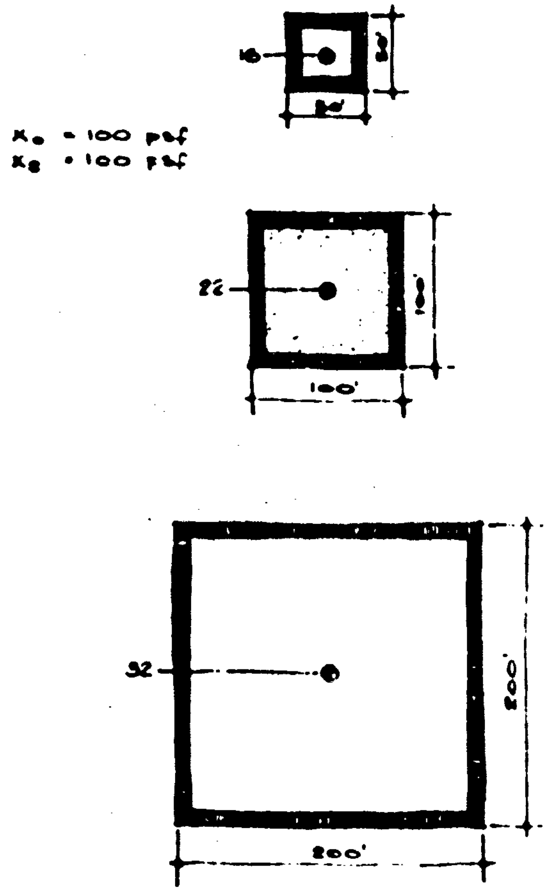


REFERENCE BUILDING SHAPE

EXAMPLE 1

Variation of Protection Factor with Floor Area

The protection factor in a building will usually increase with increasing floor area. The fallout which would have fallen on the ground around a small building will be on the roof of a larger building where it will be somewhat further away from the dose point. If the walls and roof have the same mass thickness then the radiation from the roof must penetrate a greater slant thickness of material to reach the dose point than radiation on the ground near the walls. Each of these effects tends to increase the protection factor of the larger area buildings. The diagrams indicate the increase in protection factor with area of a building with wall and roof mass thickness of 100 psf. This increase in protection with area must not, however, be elevated to the status of a law. The following is an example of a case in which there will be a decrease in protection factor with increasing area. Suppose that the roof mass thickness in the example on the right were only 10 psf. Then the protection factor for the small medium and large buildings would be respectively 4, 3.5, and 3. In this case the radiation from the roof penetrates a smaller mass thickness than corresponding sources on the ground.



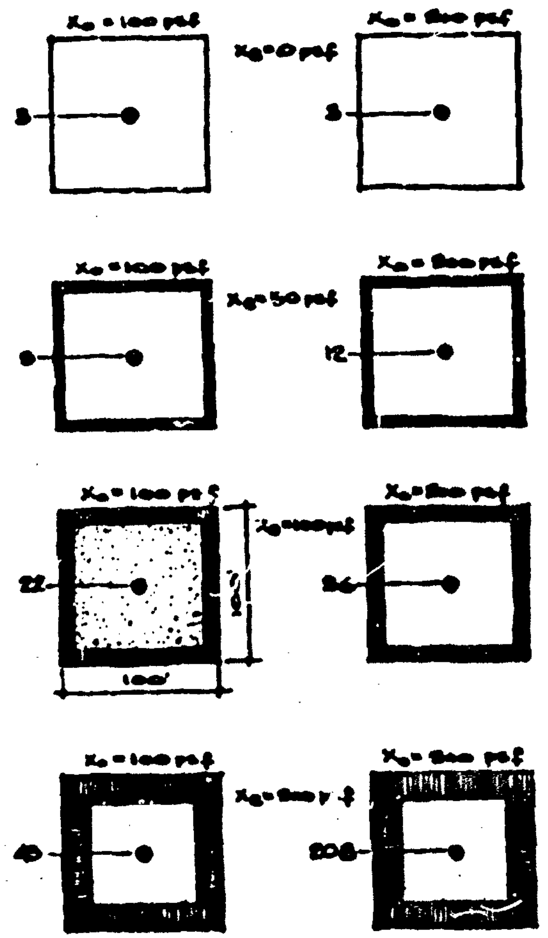
PLAN VIEWS

EXAMPLE 2A - NO INTERIOR PARTITIONS

Variation of Protection Factor with Mass

By definition the protection factor, (Pf), is the ratio of the dose rate at the standard unprotected position to the dose rate inside a structure at the detector location. The lowest value of P_f occurs when the detector is at the standard unprotected position. At this point the P_f equals 1. The P_f within a structure is always greater than one.

A man standing at the center of a cleared area 100 feet square in an infinite plane of radiation has a P_f of 3 because of the distance effect. If the man now stands in the same location with a light roof of 20 psf ten feet above the ground, the P_f is reduced to 2. This decrease results from the additional radiation received from the fallout deposited on the roof. As the roof mass is increased, the significance of the roof contribution disappears as shown in the top sketches. With a roof of either 100 psf as in Case 1 or 200 psf as in Case 2 the P_f is 3. Regardless of the roof mass, it can never be greater than three since the radiation reaching the man comes almost entirely from the ground. As the wall mass thickness is increased, the P_f increases until the roof contribution once again becomes the main factor. At this point it is necessary to increase the mass thickness of the roof to produce any noticeable difference in the P_f.



CASE 1 CASE 2

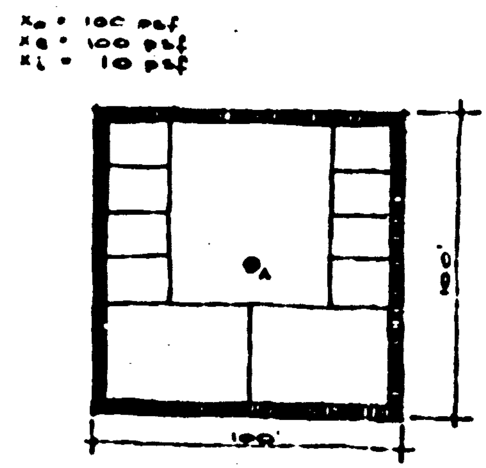
EXAMPLE 28 - LIGHT INTERIOR PARTITIONS

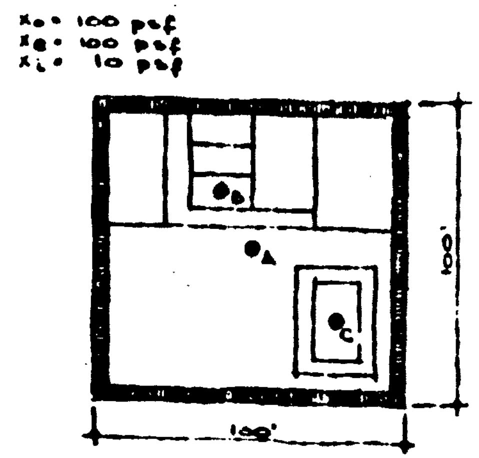
<u>Variation of Protection Factor with Mass</u>

In this example the effect of light interior walls on the protection factor is considered. The outside wall and roof masses and dimensions are those of the standard reference building.

At point A in the two figures on the right, the P_f is essentially the same as would exist if there were no interior partitions. Because the interior walls have mass thicknesses of only 10 psf they give negligible additional protection relative to the massive 100 psf walls and roof.

Areas B and C in the lower sketch are enclosed by several light partitions in parallel. The P_f in these areas will be higher than at A as the effective mass thickness between the radiation and the detection is approximately 100 + 10 + 10 - 120 psf. Heavier partitions are of much greater value for shielding purposes. If the partitions in the lower sketch were made of 8 inch concrete block, for example the spaces B and C would be shielded by 100 + 55 + 55 = 210 psf and have considerably increased protection factors.





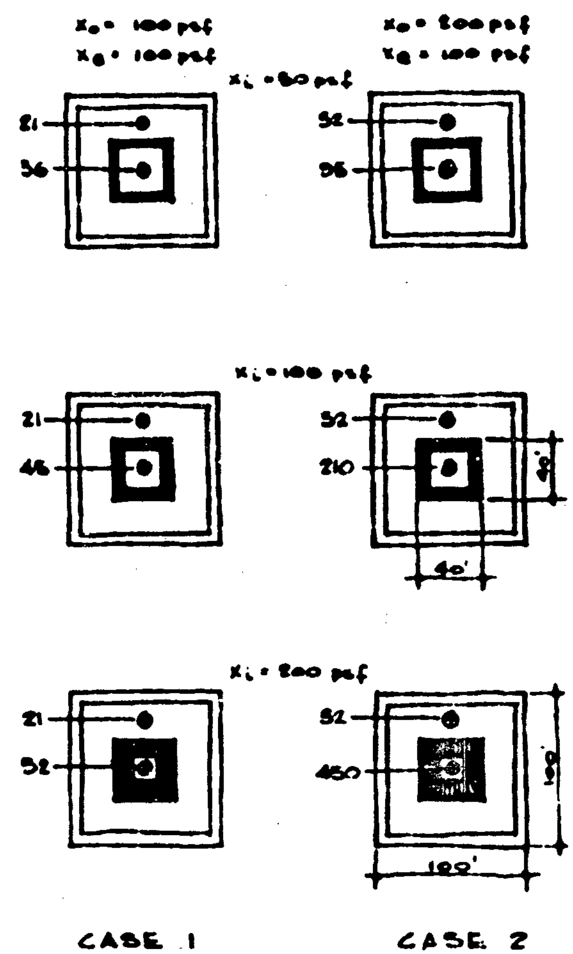
EXAMPLE 2C — HEAVY INTERIOR PARTITIONS, SINGLE CORE

Variation of Protection Factor with Mass

The sketch shows how the heavy interior partitions affect the protection factors. Case 1 with a 100 psf roof shows little variation because of the large roof contribution. Since the total wall mass thickness is relatively large (150 to 300 psf) compared with the roof mass thickness (100 psf) the major contributor is the roof. Case 2 shows how effective a heavy interior partition is once the roof contribution is reduced.

A single roof slab with a mass thickness of 200 psf is equivalent to a 16 inch reinforced concrete slab. This is excessively costly in most cases, but if the same mass thickness occurred as four 4 inch slabs the concept of the core shelter becomes much more realistic. An additional consideration can be noted here, that is, how much better the lower floor of a three or four story building is compared to the floor of a one story structure as far as the roof contribution is concerned.

The bottom example in Case 1 and the top example in Case 2 show that the protection factor in an area is determined primarily by the least massive of the enclosing elements whether it be the roof or the walls. In Case 1, for example, increasing the wall thickness from 100 psf to 200 psf results in only a slight increase in protection factor since the roof is the weak element in the radiation shield.



EXAMPLE 20 — HEAVY INTERIOR PARTITIONS, DOUBLE CORE

Variation of Protection Factor with Mass

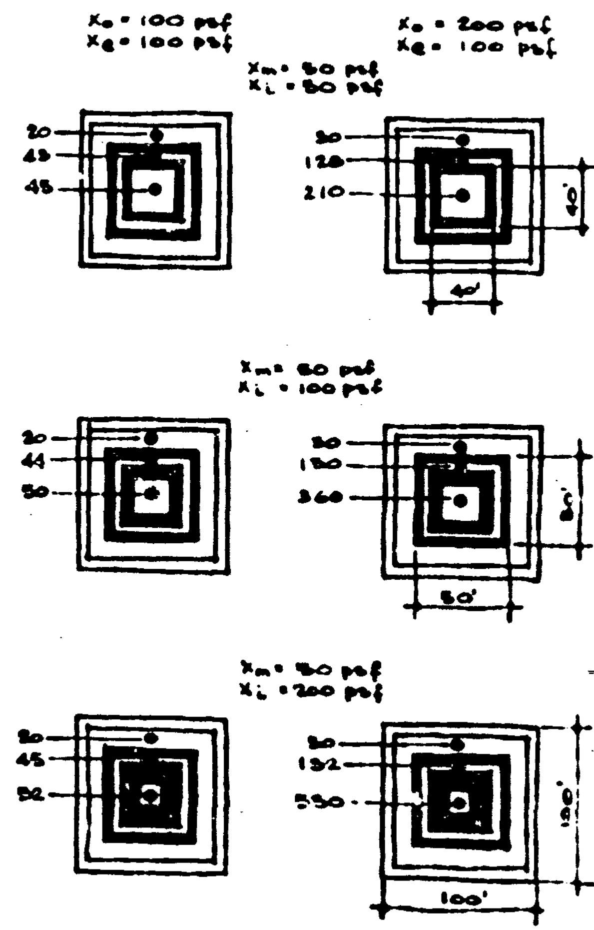
The Examples in this section are useful in understanding the modulation concept which is explained on page 3-37.

This concept envisions a small central core area with a high protection factor surrounded by a larger area with a somewhat lower protection factor.

In this example the variations of protection factor are similar to those for a single core. Again there is a large roof contribution to the dose in Case 1 with X_o = 100 psf. Thus the protection factor is determined almost entirely by the roof contribution and shows little increase with the large increase in wall thickness.

In Case 2 the roof contribution is considerably reduced by the 200 psf roof and the effect of the additional interior wall thickness is more noticeable.

Thus it can be seen that heavy multiple interior walls provide little additional protection unless commensurate overhead protection is supplied.



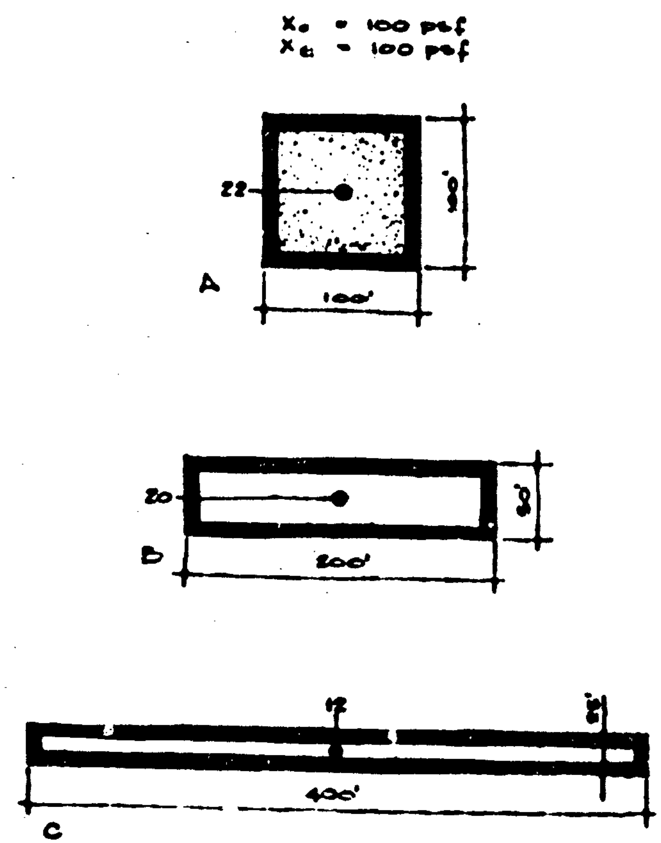
CASE 1 CASE 2

EXAMPLE 3

Variation of Protection Factor with Building Shape

This example shows the variations of protection factor within three buildings having different rectangular shapes but the same floor area and the same wall and roof mass thicknesses.

As the length to width ratio increases from 1 to 1 (in sketch A) to 8 to 1 (in sketch C) the protection factor decreases from 22 to 12. The roof contribution to the dose is nearly the same in each building because of the thickness of the roof. Therefore, the reduction in protection factor is mainly caused by the increasing proximity of ground sources to the dose points.



PLAN VIEWS

EXAMPLE 4

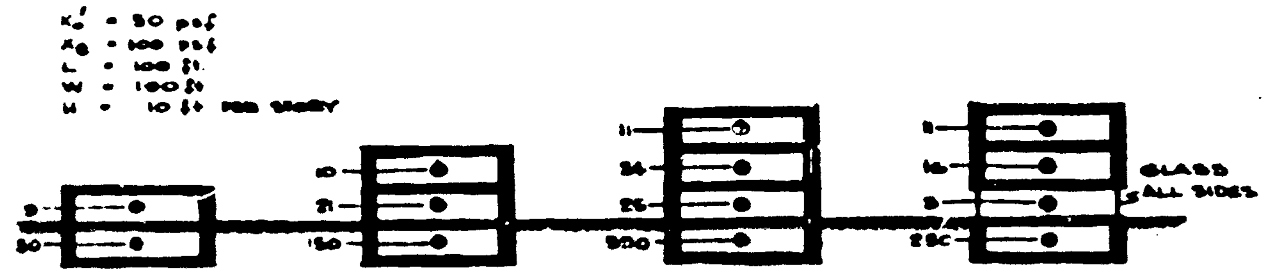
Variation of Protection Factor with Floor Height

There are two primary variables affecting the protection factors in buildings having several stories. First is the overhead mass thickness and second is the effect of the relative distance of the case point from the roof and ground sources.

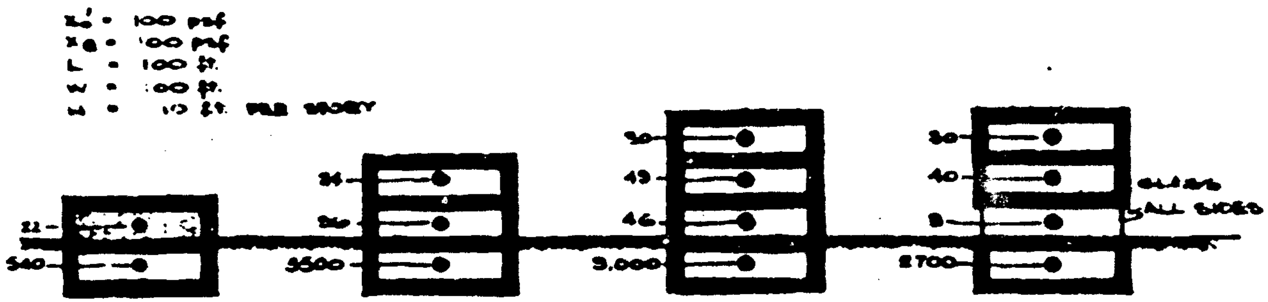
Overhead mass thickness may be in the form of one thick slab or a number of thin slabs. Thus, the protection factor calculated for the first floor of a building with a 100 psf roof mass thickness would be almost the same as the protection factor on the first floor of a two-story building with a second floor of 50 psf and a roof of 50 psf, or the first floor of a three-story building with the second and third floors at 40 psf and a roof of 20 psf.

The lower sketches at right show that in a multi-story building the protection factor increases as we move from the lower floors to the higher floors and thus get more protection from the ground sources. Then as we approach the roof the protection factor begins to decrease because we are now getting less protection from the roof sources. Thus in a multi-story building without a basement the best protection from radiation will probably be obtained in one of the middle stories.

The two sketches at the far right illustrate the radical effect glass walls have on a basement protection factor. In the upper case the basement protection factor is reduced from about 600 to 300 while in the lower case it is reduced from about 9,000 to 3,000.



SECTIONS



SECTIONS

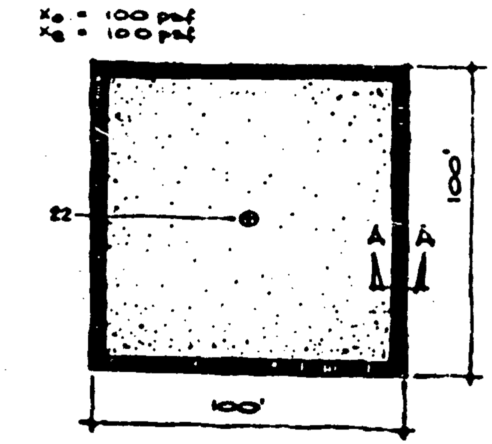
PROTECTION FACTOR VARIATION WITH HEIGHT

EXAMPLE 5

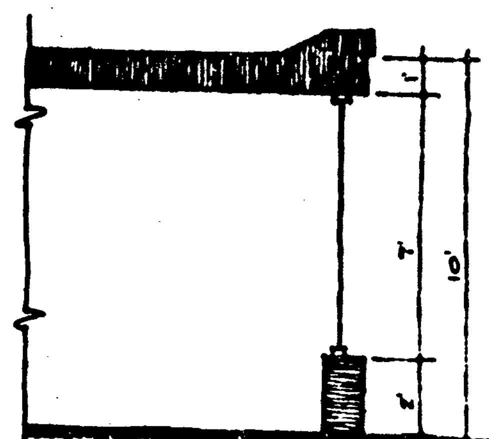
Variation of Protection Factor with Wall Apertures

A window or a door in a heavy wall is somewhat like a hole in an umbrella since it allows the radiation at that point to stream into the otherwise protected area. As in the case of the umbrella where the larger the hole the more rain will rush in also the larger the area of the apertures in the wall the more radiation will reach the detection point. Thus as the amount of aperture area increases the protection factor decreases.

In the reference case with no apertures the protection factor was 22. The table on the far right shows the effect of varying the percentage of window or door area and also the number of walls containing apertures. In this example the apertures are assumed to extend from 2 feet to 9 feet above the ground level as shown in the sketch to the right.



PLAN VIEW



SECTION A-A

30% APERTURES PER WALL

50% APERTURES PER WALL

70% APERTURES PER WALL

ELEVATIONS

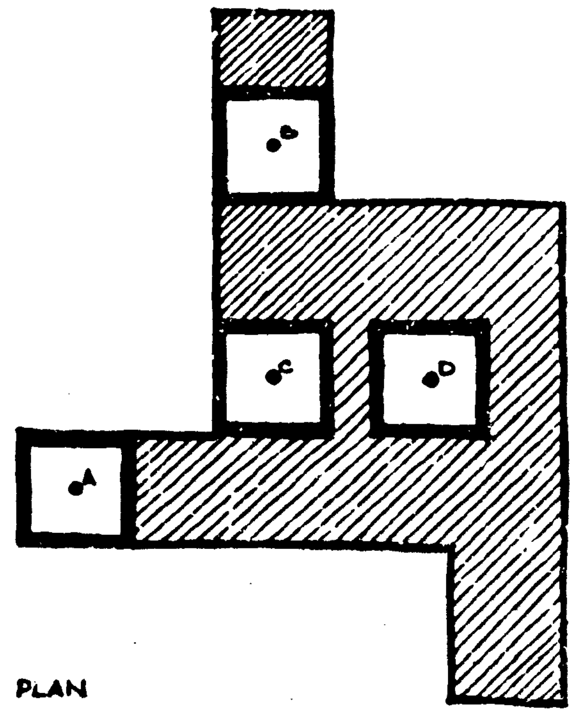
PROTECTION FACTOR			
NUMBER OF WALLS WITH APERTURES			
1	2	3	4
17	14	12	10
15	11	9	8
13	9	7	6

EXAMPLE 6

Variation of Protection Factor in Irregular Shaped Structures

The four locations shown in the sketch provide different degrees of protection. The best protection is probably provided by location D because it has the least amount of perimeter directly exposed to the ground contamination. Conversely, location A has the lowest protection factor because it has the largest portion of perimeter exposed and thus the largest number of nearby radioactive sources.

The roof contribution is the same from the area directly above each point of interest. However, in each case gamma intensities reach the points of interest from the remaining roof area. Location D receives more additional roof contribution than C, which in turn receives more than B, which receives more than A.



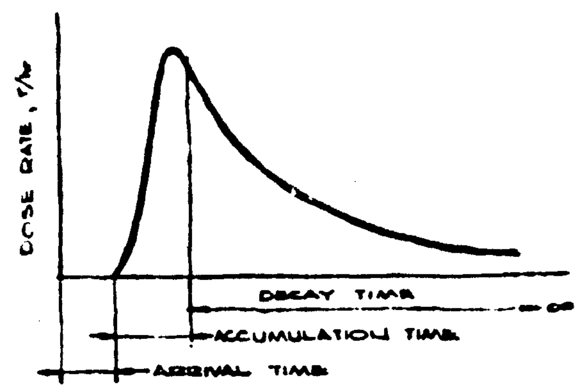
PLAN

Fallout Deposition and Decay

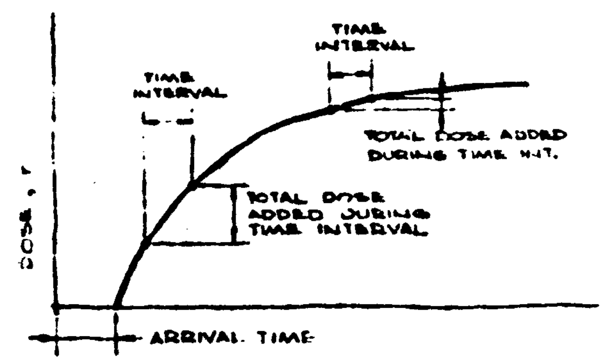
Fallout does not arrive immediately at a point downwind from a nuclear explosion. The time for the fallout to reach the point depends on the size and type of weapon, the distance from the detonation, the wind conditions, and the topography. Once the fallout arrives, it accumulates very rapidly, usually in a matter of a few hours. Thus, as shown in the graph on the right, the dose rate during the accumulation time rises very rapidly. Shortly before the fallout stops, the radioactive decay rate becomes greater than the rate of fallout accumulation and the dose rate begins to decrease. Radioactive decay continues to decrease the dose rate after all the fallout is settled. This decay effect is shown on the decay time portion of the curve on the right.

Even though the dose rate is decreasing, the longer a person is exposed to radiation, the more total dose he receives. The lower curve on the right shows how much more radiation a person would receive during a given time interval shortly after the detonation than for an equivalent time interval several days later. From this comparison, it is apparent that the first few days after detonation are the most critical as far as shielding against radioactive fallout is concerned.

This variation of dose rate with time leads to the possibility of providing smaller areas of very high protection but with limited living facilities for use in the early days after detonation and then moving to larger areas of lower protection but with better living facilities when the dose rate has decayed to a lower level. Thus it is possible to provide adequate radiation protection and adequate comfort facilities with minimum cost. Examples of this modulation concept are shown in the following cases.



DOSE RATE vs. TIME AFTER BURST



TOTAL DOSE vs. TIME AFTER BURST

Case 1

Consider a point 30 miles directly downwind from a 100-kiloton fission yield surface burst. If the effective wind velocity is 15 miles per hour, the fallout will begin to arrive about 2 hours after detonation. Assuming that the fallout is essentially complete in another two hours, the dose rate at the "standard unprotected position" (three feet above an infinite plane of radiation) will vary with time as shown in the sketch on the next page. The table gives the approximate dose rate and the total accumulated dose at the standard unprotected position for various times after the burst.

In a structure having areas with three different degrees of protection, a person could receive different doses depending on the area in which he remained. Assuming that the protection factors are 100, 20, and 10, the optimum solution would be to remain within the area with a protection factor of 100 until the outside radiation level becomes safe. This is true as long as the area is reasonably comfortable. If the area with the high protection factor is uncomfortable, it is possible to use the other portions of the structure and still not receive doses of radiation which would cause sickness or death.

Spending the first week in the highly protected area, the second week in the area with protection factor of 20 and the next five weeks with a protection factor of 10, results in the following total accumulated dose:

1st Week		2nd Week		3rd to 7th Week
$\frac{1000}{100}$	+	$\frac{1100 - 1000}{20}$	+	$\frac{1230 - 1100}{10}$

$$10 + 5 + 23 = 38r$$

A dose of 38r received over a period of seven weeks will generally have no detectable effects. It should be noted that with no protection, the dose received would have been 1230r which is a fatal dose. Thus, an "effective protection factor" of 33 was provided even though six of the seven weeks were spent in areas with protection factors of 20 and 10.

Case 2

Assuming exactly the same situation as that just investigated, what is the effect of a 2-megaton detonation rather than the previous 100 kiloton detonation? The dose rate variation is shown in the sketch, and values of dose rate and total accumulated dose are given in the table.

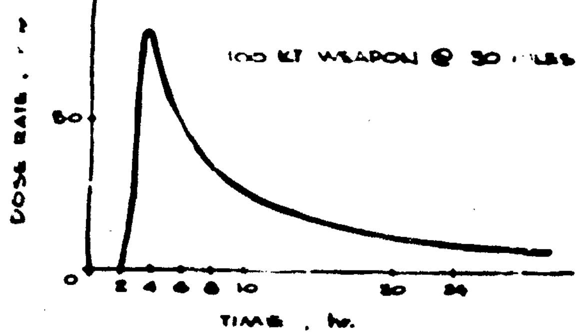
In this case, the occupant receives a higher total dose.

1st Week		2nd Week		3rd to 7th Week
$\frac{3750}{100}$	+	$\frac{4100 - 3750}{20}$	+	$\frac{4650 - 4100}{10}$

$$37.5 + 17.5 + 55 = 110r$$

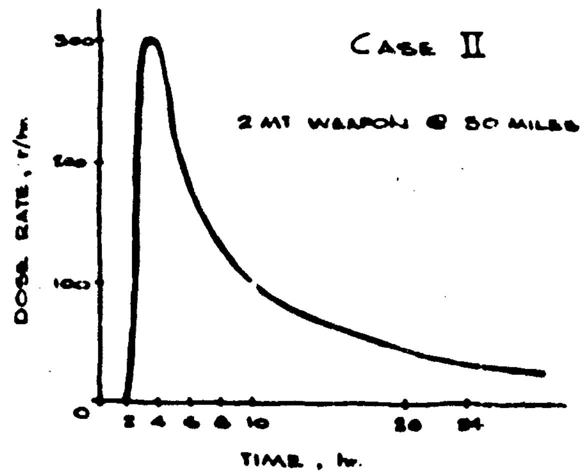
This level of radiation will probably not cause any sickness since it is accumulated over a seven-week period of time. However, it is high enough to cause considerable concern over long-range biological effects. In this case it might be advisable to remain in the area having a P_f of 100 for most of the first two weeks except for short periods in the lesser protected area.

CASE I



100 KILOTON WEAPON @ 30 MILES		
TIME AFTER BURST (days)	DOSE RATE (roentgen/hr.)	TOTAL ACCUMULATED DOSE (roentgens)
1	9.0	625
7	0.9	1000
14	0.4	1100
49	0.09	1250
INFINITE	0	1750

CASE II



2 MEGATON WEAPON @ 30 MILES		
TIME AFTER BURST (days)	DOSE RATE (roentgen/hr.)	TOTAL ACCUMULATED DOSE (roentgens)
1	35.0	2400
7	5.5	3750
14	1.5	4100
49	0.55	4650
INFINITE	0	6600

Concept for Modulating Shelter

A study of the radioactive decay has led to the concept of modulating shelter.[12] Modulating shelter is the term applied to protective areas designed with the idea of alternating between areas of high protection and areas of lower protection.

The basic idea is to design the shelter areas economically by including in the highly protective areas only those activities which require appreciable lengths of time. The occupants stay in the area of high protection during the initial period of intense radioactivity. The amount of time spent in this area depends upon the outside dose rate and the protection factors of the respective shelter areas. As the dose rate decreases the occupants are able to use adjacent areas of lower protection for short durations, for example, the use of kitchen and toilet facilities adjacent to the highly protected area.

The main reason that this concept of modulation can be implemented is that most of the total dose an occupant receives will come from a steady accumulation of radiation over a prolonged time. However, the occupant can remain for a short duration in an area of high dose rate with very little increase in his total accumulated dose. Thus lower protection factors can be tolerated in rooms or spaces in a shelter with short time occupancy (toilets, storage, and maintenance) than in areas of long occupancy (living and sleeping areas).

As the dose rate decreases further, the time spent in areas of lower protection can be lengthened. The area of lower protection can also include the region outside the shelter until finally, when the outside dose rate has decreased sufficiently, near-normal living can be resumed.

The concept of modulating shelter offers a maximum degree of protection at a minimum cost. Basic necessities and comforts required by personnel can be provided in several areas with varying degrees of protection rather than be included within one large highly protected area.

For modulation to work successfully, instruments must be provided to enable personnel to measure the dose rate in the respective shelter areas and the total accumulated dose which they have received.

Instrumentation

Two types of radiation meters have important uses in fallout situations: dosimeters and survey meters.

Dosimeters measure the total radiation dose in roentgens received during an exposure period. A typical dosimeter is the self-indicating quartz-fiber electrostatic dosimeter (a fountain-pen size device) with a range of 0 to 20 roentgens or 0 to 200 roentgens.

Survey meters measure dose rate expressed in roentgens per hours. A number of survey meters have been developed with various sensitivities for measuring gamma and/or beta dose rates. These devices weigh several pounds and are about the size of a child's shoe box.

In a practical sense a survey meter is the most essential

item for survival in a fallout field. Without a survey meter one is blind to the source of the danger. However, with a survey meter one can "see" and avoid hot spots, seek optimum shelter, and effect repairs of radiation leaks into shelter spaces.

<u>Ingestion Hazards</u>

Radioactive material can enter the body by ingestion, inhalation, or through wounds or abrasions in the skin. The principal problem following a nuclear explosion may be expected to be ingestion due to the consumption of food and water contaminated with fission products. The amount of radioactive fallout absorbed by inhalation will probably be relatively small. The nose can filter out all particles over 10 microns (0.001 centimeter) in diameter. Most of the fallout particles descending within 24 hours after the burst, the critical period of highest activity, will be considerably larger than 10 microns.

Every reasonable precaution should be taken to prevent contamination of exposed water and unpackaged foodstuffs with fallout particles. A very small quantity of radioactive material present in the body can produce considerable injury. For example, the maximum permissible peacetime concentration of the isotope Strontium - 90 in the body is of the order of a hundred-millionth of a gram. A 2 Megaton fission yield bomb-produces about 1000 grams of Sr-90.

Internal radioactive sources are particularly dangerous because radiation exposure of various organs and tissues is continuous, subject only to depletion of the quantity of active material in the body as a result of radioactive decay and biological elimination processes. Since the body tissues are nearer the source of radiation and are not shielded by intervening mass, alpha and beta particles become major sources of biological damage.

The ingestion problem is aggravated by the tendency of certain chemical elements to concentrate in specific tissues or organs, some of which are highly sensitive to nuclear radiation. Iodine, whether radioactive or not, tends to concentrate in the thyroid gland; whereas strontium is a bone seeker.

There is sor , factual experience with fallout as an internal hazard. As a result of the Bikini Atoll high-yield nuclear burst in 1954 fallout was deposited on the Marshall Islands. The Islanders, unaware of the significance of the fallout, ate contaminated food and drank contaminated water from open containers for two days or so. Internal deposition of fission products resulted mainly from ingestion rather than inhalation because, in addition to the reason given above, the radioactive particles in the air settled out fairly rapidly, but contaminated food, water, and utensils were used all the time. In spite of the fact that the Marshallese people lived under conditions where maximum probability of contamination of food and water existed, and that they took no steps to protect themselves in any way, the degree of internal hazard due to fallout was small.

Shielding References

The material in the section on shielding considerations was intended to be introductory. In order to compress radiation shielding, a graduate level nuclear engineering subject, into a few pages it has been necessary to take some liberties with the truth. Half-value thicknesses, for example, are not rigorously definable; and it is only approximately true that equal mass thicknesses result in equal attenuation. Still, these simple rules of thumb are valuable, particularly for architectural planning, provided it is understood that they are approximations, and that better numerical values should be obtained before the final stones of the detailed design and construction.

For further reading in greater depth and breadth refer to References 13 through 19 at the end of this chapter.

STRUCTURAL PLANNING ASPECTS

Careful planning is essential for an economical structural solution. The structural system must be developed simultaneously with the progress of the architectural plan. Factors that will influence the structural system include aesthetics, function, and integration with mechanical systems. To economically incorporate radiation protection into a building, shielding principles must be considered in the planning. Any inherent residual radiation and low level blast protection may be achieved through effective planning and selection of the structural system. The selection of the structural system in relation to its span is an important planning consideration in conventional design and it becomes even more important in the case of a structure planned to resist low level blast and provide inherent fallout protection.

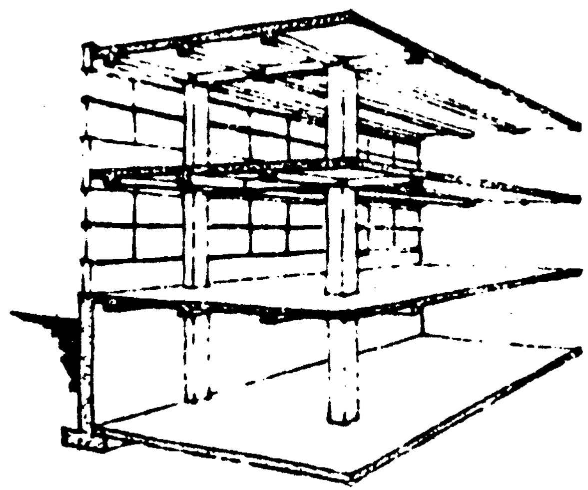
Generally, as the span increases, the type of framing will need to be changed in order to function most economically This progression can be listed as follows: simple beams, continuous beams, trusses, bents, arches, and suspension systems. Material has a marked effect on the economy of the span whether it be steel, reinforced concrete, prestressed concrete, or wood.

Conventional wind loadings are not severe enough to require a structural system that will have a large degree of inherent blast resistance. If the protection criteria for low level blast is incorporated in the initial planning, resistance is almost automatically provided for other disaster loadings such as earthquakes and hurricanes. More

specifically, some of the major factors that contribute to effective structural planning for integration of protection are:

1. Orientation of structure
2. Location of protected area within this structure
3. Selection of exterior wall material
4. Arrangement of partitions for use of missile shields
5. Increased strength of structural connections
6. Door location, door selection and hardware detailing

In order to understand the inherent protection which might be achieved through the appropriate selection of the structural system it is necessary to review the various characteristics of different structural systems. The characteristics should be studied as they relate to the integrated planning for normal and emergency occupancy and are included below



TYPICAL POST AND BEAM CONSTRUCTION IN CONCRETE

Post and Beam

The most common system in use, post and beam construction can be erected in wood, metal, or concrete. Trusses bents, open web joists and a variety of structural steel shapes fall into this broad class of construction in addition to the rectangular sections of wood and concrete.

COLUMNS SUPPORTING FLAT SLAB AND FLAT PLATE CONSTRUCTION

Advantages

It possesses a high degree of structural integrity, especially in the case of monolithic concrete structures. Design and fabrication procedures permit relatively economical construction.

Disadva[illegible]

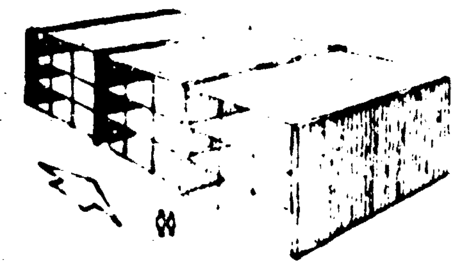
Large [illegible] ered areas are frequently used for normal [illegible] but are undesirable for protection because [illegible] provide little protection and they can become [illegible]. Of course, if panels are selected to withst[illegible] loads, the structure must be capable of resisting the load transferred by the panels. Flexibility of parti[illegible] arrangement is limited by protruding exposed beams unless furred ceilings are provided. This system does not lend itself for integration of mechanical and electrical distribut[illegible] systems.

Modifi[illegible]ns for Inherent Protection

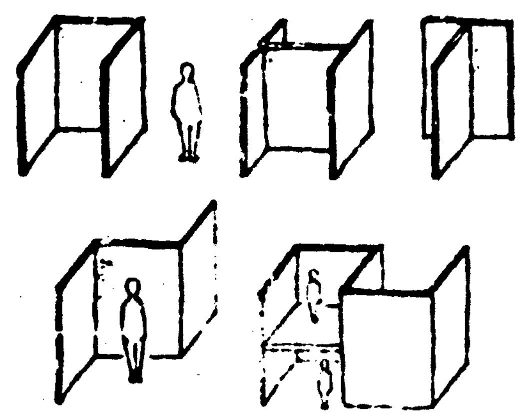
If a core is developed in a section of the building it [illegible] utilities in addition to providing a structurally sound [illegible] for protection. Reinforced concrete is generally the material needed. Even with a core, masonry or other heavy exterior wall could be used to provide additional radiation protection. Use of flat slab could increase headroom somewhat and provide for maximum vertical space utilization which becomes of significance in the protected area

Shear[illegible] Construction

[illegible] of shear wall seems to be the best structural system where lateral loads effect the design of aboveground structures. [illegible] reinforced concrete or reinforced masonry [illegible] walls. For the floors and roofs, rein[illegible] is preferred, but rolled steel beam sections [illegible] if they are designed to transmit the blast loads [illegible] walls.



BASIC SHEAR WA[illegible] FOR
RESISTANCE TO LA[illegible] LOADS



STRUCTURAL PART[illegible] SERVE
AS SHEAR WAL[illegible] COLUMNS

Advantages

The superstructure is very efficient in blast resistance and is useful where large unobstructed exterior window areas are desired between the shear walls. The system is superior to conventional post and beam in regard to strength and cost. No separate wind bracing is needed because the shear wall provides inherent wind resistance.

Disadvantages

There is a limitation to the percentage of apertures in the sheer wall because it should act as a homogeneous unit.

Modifications for Inherent Protection

A reinforced concrete shear wall system provides maximum protection when arranged transversely and in pairs — thus forming a core. Additional reinforcing must be placed around large openings in shear walls.

Arch and Domes

Cylindrical shells and dome structures are generally more stable from the conventional structural viewpoint than post and beam construction. Concrete can be used in any shape. However, the construction cost of curved surfaces is generally high.

Arch and dome systems possess high efficiency from a conventional structural standpoint. Also the blast load is less than a rectangular structure because of its streamlined surfaces reducing the build-up of the reflected pressure. Preforming and prestressing could increase structural efficiency considerably, although presently the processes are not economical in the United States except for relatively straight members.

Disadvantages

Flexibility of movable partitions and modular relationships become complicated. Fabrication of installation of mechanical and electrical distribution systems are intricate. In many cases, a large portion of the volume enclosed cannot be fully utilized for functional purposes.

Modifications for Inherent Protection

Additional resistance could be obtained by introducing a rib network on the inside of a concrete shell.

Load Bearing Construction

Although a masonry load bearing construction is not used extensively today, this type of structure offers good radiation shielding, especially near the base of a multistory structure where walls may be exceptionally heavy.

Advantages

Many large openings in the walls are not desirable; however blast resistance and good radiation shielding are achieved by means of few apertures.

Disadvantages

If the walls are of reinforced masonry, only low pressure blast resistance can be achieved economically.

Modifications for Inherent Protection:

There are many existing areas in load bearing buildings which are adaptable for fallout shelter if proper shielding materials are used.

MECHANICAL PLANNING ASPECTS

Air

Shelter needs with respect to air have previously been mentioned but the means for satisfying them have not been discussed and the types and quantity of equipment and requirements for its operation have considerable significance with respect to architectural planning for shelter.

Oxygen and Carbon Dioxide

During the period of shelter occupancy there will be a need for oxygen supply and carbon dioxide removal, the amount depending on the time-volume relationship. Oxygen cylinders or chlorate candles for producing oxygen might be provided for the extreme emergency of sealed-up conditions. In fleet-type submarines, carbon dioxide is removed by the use of lithium hydroxide as an absorber, and the same means might be employed in shelters. If no sealed condition is anticipated, an adequate ventilation system will generally be sufficient for supplying oxygen and removing carbon dioxide. Since inlets and outlets must be kept to a minimum size to protect from blast and radiation, natural ventilation is extremely limited. A manually operated blower may suffice for small, sparsely populated shelters, but automatic fan operation is imperative for large underground shelters. The quantity and proportion of fresh and recirculated air commonly recommended for shelter work is 3 cfm and 12 cfm respectively, making a total of 15 cfm. This is considerably less than the 10/20/20 cfm used for conventional design. Based solely on the air intake and circulation requirement, the capacity of a convertible shelter could be about double the conventional occupancy. The actual final capacity depends on other factors however, including activity of occupants and amount of air infiltration.

Effective Temperature

Cooling is the most critical factor in maintaining the effective temperature within the desired range. Heat that arises from generators, motors, lights, and occupants must be removed. Frequently, ventilation is sufficient to cool the shelter space. However if overcrowding is anticipated, an air conditioning system must be installed. Heat sinks might be used to reduce the cooling load. Also, it is desirable to place a maximum of shelter periphery walls and floors adjacent to dome earth to effect maximum dissipation of heat.

In cold weather a heating requirement may exist for a short time at the beginning of shelter occupancy. Blankets and warm clothes should provide satisfactory warmth for this initial period. In a convertible shelter, the space would be heated continuously. Electric space heaters are desirable for emergency use in all circumstances. Space heaters utilizing fuels are to be avoided because of the gases and fumes which are given off and because they consume oxygen.

Chemical, Biological, Radiological Agents (CBR)

CBR agents may be excluded from the shelter area by two principal methods: (1) use of filters, (2) provision for a

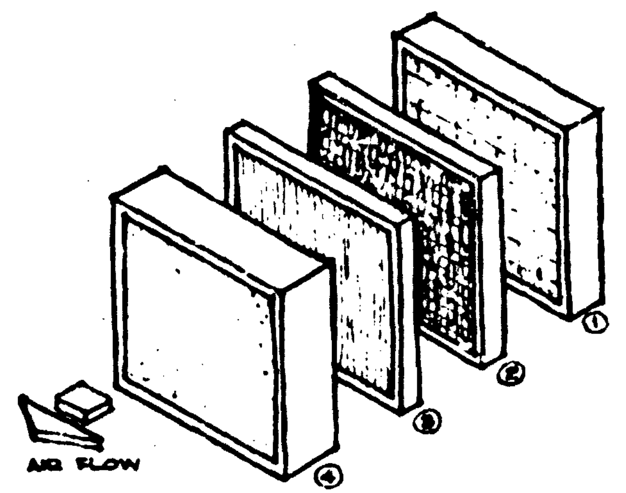
slight positive internal pressure.

In small shelters filters to exclude fallout particles may not be needed because of the low intake air velocity. However, some protection may be desirable against chemical warfare (CW) and biological warfare (BW) agents. Since a slight internal pressure is impractical for small shelters because of lack of equipment, face masks are recommended in this case. The mask is an effective protective measure inasmuch as 95% of CW and BW agents enter through the nose and mouth.

For high velocity intake, filters are needed for screening outside air depending on the agent and the location of intakes. For radioactive particles conventional filters and air conditioning systems are effective. In addition, maintaining a positive pressure of about 0.6 inches of water will prevent entry of the agents through cracks and crevices. (Normally, this is difficult to achieve in conventional construction). Use of air locks would restrict pressure loss at entrances.

For low volume intake during emergency conditions sand filters have a number of advantages, including ability to reduce intake air temperatures, to filter out small particles, and to attenuate blast pressures. Special filter assemblies such as indicated in adjacent sketch should be used for screening CBR agents.

The location of filters is important because of the accumulation of radioactive materials. Therefore, attentions must be given to proper shielding and duct configuration. In addition, radioactive disposal of filters must be considered in relationship to shelter operational problems.



①	PRE - FILTER	STRAW OR HAIR
②	SECOND PREFILTER	ORDINARY FURNACE FILTER REMOVES RADIOACTIVE DUST
③	PARTICULATE	1 OR ½ MICRON SIZE REMOVES BIOLOGICAL AGENTS
④	ACTIVATED CHARCOAL	REMOVES CHEMICAL WARFARE AGENTS, SMOKE

CBR FILTER

Blast Pressures

When subjected to very low overpressures (1/2 psi) certain types of filters will be damaged. At higher overpressures (5 psi) eardrums may be ruptured. Therefore, all air inlets and outlets should be protected from blast overpressure as well as flying debris. Blast closure valves of various types are available. Actuation of the valve is usually one of three methods — manual, direct actuation by the blast, or remote actuation by a thermal blast or nuclear radiation detector.

Water Supply

It is axiomatic that a supply of water is essential in a shelter. The purposes for which water is needed have already been listed and minimum quantities have been stipulated. The present discussion will be concerned with the sources of the water, distribution and storage. All of these considerations will effect architectural planning at some stage, the earlier the better.

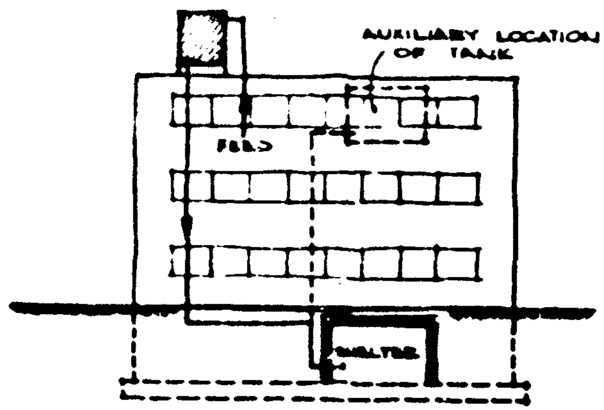
The public water supply system should be used whenever possible. It is possible, however, that the public supply will be available after an attack. Private supplies or adequate planned storage fed from the public supply will usually be necessary. In considering the public water supply and its use for shelter purposes, special attention should be given to the distribution system. The greatest danger of interruption occurs at the point where the main enters the building. Here, a flexible connection will enhance the chances of continuing water service.

Maintaining adequate water pressure after a blast, when many mains are broken and when fire-fighting flow is greatest, will be made easier by eliminating dead ends through looping the mains and by a control system to shut off broken sections as quickly as possible.

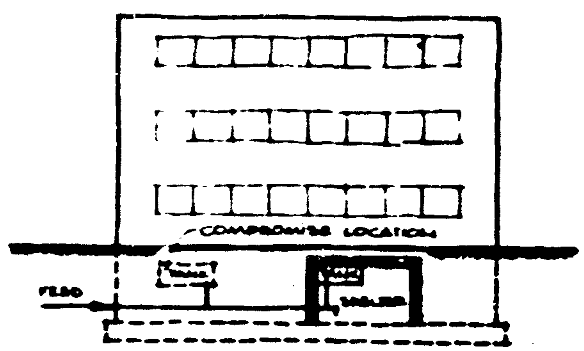
Individual water supply sources should be provided for shelters, even though the quantity is greatly reduced from that normally supplied to the building. Water storage tanks are the most positive means of assuring an adequate supply. These tanks may be installed in series in an existing water line to assure freshness when needed. Other locations may be dictated by these space requirements. It may be better to locate the tanks outside the shelter area or even outside the building if there are provisions for keeping the water fresh, and for protecting the tanks and lines against excessive pressures.

A tank located above the building is vulnerable to blast damage since it is drag-sensitive, but has the advantage of providing adequate pressure through gravity. A tank located above the shelter but within the building will reduce the vulnerability to blast, but will retain the advantage of gravity feed. A tank located within the shelter encroaches on valuable space needed for other purposes, but has advantages in ease of control and natural protection. A tank located within the building but just outside the shelter is a good compromise. A buried tank with sufficient ground cover will be protected against radiation and low level overpressures.

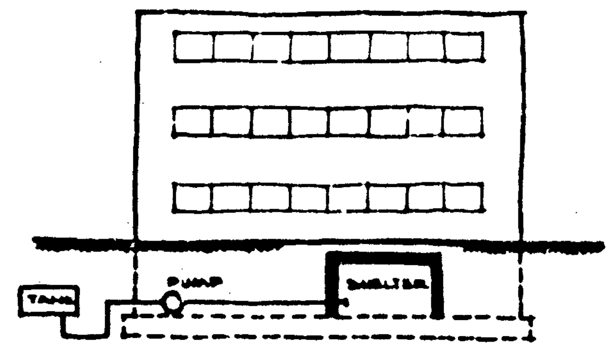
Water from any tank should be changed periodically to keep it fresh. Distribution lines from tank to building need flexibility, particularly at the point of entry. Control of supply and distribution is more difficult than with an inter-



TANK ABOVE SHELTER



TANK WITHIN SHELTER



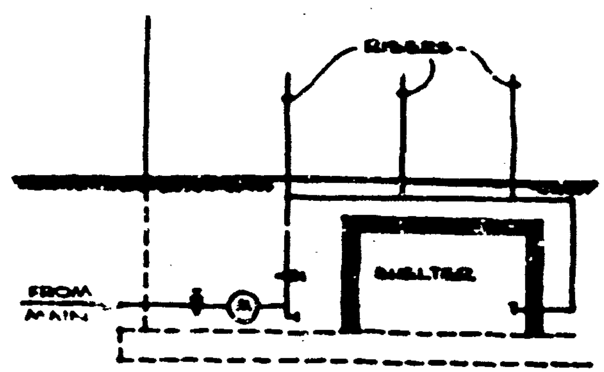
BURIED TANK

nal tank, but can be handled satisfactorily with good planning. In most cases, pumps will be required to provide adequate pressures. Surface reservoirs and underground reservoirs may replace tanks for large volume supply, particularly for non-potable water. Surface reservoirs are relatively easy to construct but the reservoir complex is highly vulnerable to blast damage and to radioactive contamination. On a long term basis, the water can be decontaminated by coagulation and filtration of the contaminants, but immediate use for shelter purposes might be risky. Underground reservoirs are costly to construct but their use eliminates many of the faults of the surface reservoirs.

Wells are excellent sources of water supply in that they provide a dependable flow of cool, uncontaminated water.

However, private wells would not be economically feasible unless they were used to serve the daily needs of the building occupants and not designed solely for emergency purposes. If wells are used, the need for pumps, pneumatic tanks, motors, engines, and auxiliary equipment and supplies must be considered. All equipment must be readily accessible for maintenance and repair. It should be possible to operate the pump manually in the event of an electrical breakdown to provide at least the minimum amount of potable water needed.

There are other sources of water for emergency use in a shelter in addition to those already discussed. Water distribution piping within a building contains a large quantity of water which will be uncontaminated after an attack provided the main entry valve is closed prior to the entry of the contaminated water. By proper manipulation of



EMERGENCY USE OF WATER IN DISTRIBUTION LINES

other valves, and through intelligent planning of piping runs, most of this water can be made available to the shelter area.

The location of hot water storage tanks within or adjacent to the shelter area will provide a large source of water which is continually refreshed in normal operation of the building. The only thing necessary for tapping this supply is the closing of the intake valve to prevent contamination of the contents. Pneumatic tanks, suction tanks, and other storage tanks within the building used for normal operation of heating and water distribution systems can serve as emergency sources of water for the shelter.

Water stored in bottles or cans may provide the minimum quantity of potable water needed for limited shelter stay. Such water will remain fresh and drinkable for extended periods of time under ideal circumstances. Sufficient storage space must be planned for and provided within the shelter to accommodate the necessary canned water.

The type and quantity of food provided in a shelter will affect the amount of water needed for drinking purposes. Most, if not all, of this water can be supplied in the form of fruit juices and soup. When the supply of potable water is apt to be limited, salty and highly seasoned foods should be avoided. Since potable rather than non-potable water supply is usually the more critical item, effort should be made to provide as much of the needed quantity in foods as possible.

Conservation of water within the shelter may be necessary in extreme emergencies. It is now possible, for example,

to purify waste water to the point where it is perfectly safe and palatable, and to accomplish this in a small space with minimum equipment. There still remains the psychological hazard of drinking human wastes, even though safe.

By careful planning and control, the same water may be used to serve several purposes. It may be used first to wash dishes, then to do some essential laundering, and finally to flush plumbing fixtures. Even the water for drinking purposes should be carefully controlled in quantity if the supply is minimal.

Finally, in addition to the water required for human consumptions, plumbing, and machinery operation, thought should be given to needs for fire-fighting within the shelter space. Any fires within a closed space could be disastrous. Therefore every effort should be made to provide adequate control at the incipient stage. If the space already contains a sprinkler system or standpipe and hose, the only problem seems to be the storage of water to feed the existing piping with proper valve controls to isolate the shelter area. If no fire fighting installation exists, proper type potable extinguishers should be provided, and a supply of non-potable water should be reserved for the larger fires, should they occur. The use of fire-fighting equipment will place an added burden on both ventilation and drainage systems. Therefore, the designer needs to consider all the subsystems in a shelter as an integrated package in order to have the shelter function adequately.

<u>Sanitation</u>

Provisions for sanitation in a shelter space must be made at the initial planning stage for a satisfactory and economical solution. These provisions include space for fixtures and equipment, for needed human circulation, for piping and vents, for disposal equipment, and for necessary storage. All wastes may be grouped into four classes according to their nature and the means required for disposal:

a. human
b. wet garbage
c. dry trash
d. polluted water from machinery and various processes.

Planning for sanitation in a convertible shelter should begin with the normal functions of that space. If such provisions are adequate, it is possible that many of the needs will be satisfied. Design of the water supply system to serve plumbing fixtures is accomplished in the usual manner. In thinking of shelter needs, however, the designer should consider the advisability of using a non-potable water supply from storage tanks in the event of a rupture in public supply during an emergency.

Space requirements for sanitation includes toilet rooms with the number and type of fixtures set by requirements for normal space function, storage space for emergency fixtures and supplies, storage for water, space for water distribution, drainage, and vent lines. Since requirements differ so widely for normal functions, no attempt is made here to discuss these space requirements.

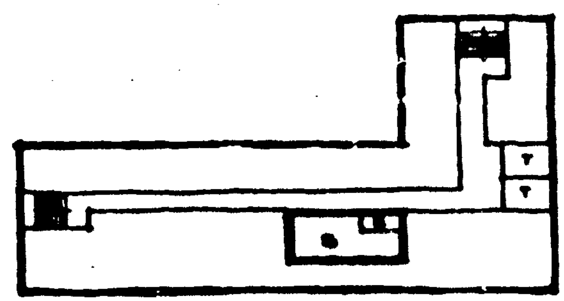
Privacy is normally considered in locating toilet rooms and also should be given consideration in planning for shelter layout. At the same time, it is highly desirable that toilet facilities be located within or immediately

adjacent to the space being developed as a shelter. Drainage and vent pipes, ventilation shafts, and access spaces must be so located as to permit servicing, while at the same time prevent radiation from entering the shelter space through a direct line to the exterior. Noise can be reduced by planned location and possible insulation of those pipes and shafts.

A limited supply of electric power may be needed for operation of the sanitation system. Power may be required for vent fans, garbage disposal units, grinders attached to water closets (a new development), sewage ejectors, other sewage pumps, some incinerators, and necessary lighting. A continuing source of electric power is therefore necessary for those portions of a sanitation system needing power which will be used when the space is converted to a shelter. The designer must consider and provide for necessary distribution lines from the emergency sources of power.

Augmentation of normal facilities may be desirable and, under certain conditions, even imperative in a convertible shelter. If the selected space is too far removed from normal facilities — toilet facilities, incinerators and other waste disposal equipment — additional emergency equipment may be necessary. In this situation, storage space must be provided for portable chemical toilets, bedpans, plastic bags, and cans, and space must be arranged for private use of this equipment. In addition, consideration should be given to storage of special items such as waterless cleaners, dry chemicals, and disinfectants.

As an alternative to providing all necessary sanitary facilities within the shelter space, it may be possible and even desirable to rely upon facilities for normal building occupancy even though the facilities are in an area with less protection. In this situation, only the most austere provisions would be provided within the shelter area and all occupants might suffer some inconvenience for the first day or two of shelter occupancy. Then, as the level of radioactivity decreased, occupants of the shelter area could leave the better protected space for short periods of time to use the lesser protected permanent toilet facilities.



S - SHELTER SPACE
E - EMERGENCY TOILETS
T - PERMANENT TOILETS

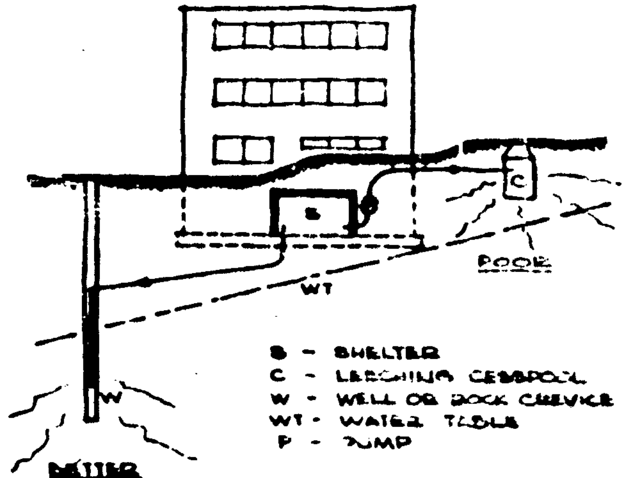
COMBINED USE OF TOILETS
IN AND OUT OF SHELTER SPACE

Whenever possible, a central system for sewage disposal should be used. If the building normally is connected with a private disposal system, such as a septic tank and drain field, some slight additional attention to piping connection with the building is all that is needed. If, however, a public system is used for normal operation, consideration should be given to emergency disposal into cesspools or rock crevices. These means would serve emergency periods only. In the event that cesspools or wells are used, they should be so located with reference to the building that danger from seepage through the walls is minimized. A sewage ejector may be needed to place the sewage in the most desirable location.

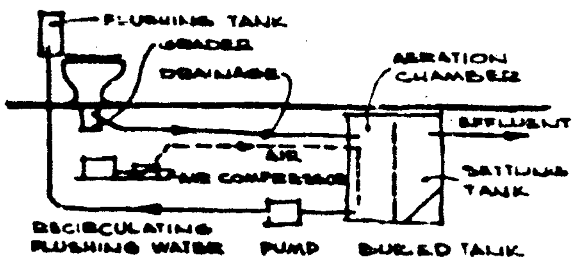
Surface disposal of waste matter which is polluted and which is a potential health hazard is not to be considered except in an extreme emergency. Adequate foresight in planning the shelter space may eliminate the need for this method.

The water supply, non-potable as well as potable, is frequently a critical item in a shelter. Water-flushed toilet fixtures are most desirable, but they also create a serious drain on the limited water reserve. Some newer developments in sanitary fixtures and systems promise to alleviate this condition and therefore deserve consideration by the shelter planner. In one such system (Sanitol, Inc., Lafayette, Indiana) a grinder is used under the fixture and treated waste water is recirculated for flushing action. A power supply is needed for the grinder and pump.

If the shelter contains a dispensary, infirmary, or a more



DISPOSAL OF SEWAGE



THE SANITOL SYSTEM

elaborate medical facility, plumbing fixtures must be provided to satisfy at least emergency needs. Even without a separate medical facility attention to plumbing details will keep to a minimum the more serious medical problems which might otherwise be created within the shelter.

Dry rubbish can most easily be disposed of by burning in an incinerator. However, this would use up oxygen, create gases to be disposed of, and increase internal temperature. For these reasons, it may be necessary in a shelter space to provide storage for the dry rubbish until it can be removed to other areas. Wet garbage can be incinerated or stored in suitable air-tight containers until such time as it can be removed to the outside. If stored, ventilation of the storage room is desirable and a cool temperature is preferred, use of disinfectants will help control odors, decay, bacteria, and rodents.

Decontamination facilities will be desirable for most shelter areas. The extent of these facilities is dependent on the purpose of shelter and the mission to be accomplished by its occupants. Essentially for a decontamination entry system are:

(a) a continuous flow of air outward caused by maintaining a slight positive internal pressure
(b) necessary air locks to maintain the pressure differential
(c) undressing areas with provision for disposal of contaminated clothing
(d) showers with adequate water supply
(e) dressing areas with provision for issuing fresh clothing.

It is with the shower area that the present discussion is most concerned. Water supply and disposal for the decontamination facility may be based on a flow of three to five gallons perminute per single shower area. An average time for showering is one to two minutes. Based on this unit figure, the total expected flow and drainage for these showers may be approximated for any shelter installation.

General decontamination of surface adjacent to the building may demand large quantities of water, but this operation can be delayed until it is relatively safe to abandon the actual shelter.

Sanitation facilities needed in a particular shelter will depend somewhat on the diet provided for the occupants. A proper balance between roughage and thin foods will tend to create conditions which are normal in this respect. A planned constipation situation may relieve the load on the plumbing facilities, but create psychological and sociological problems. However, the sanitation facilities should be planned for the normal diet situation.

Power

The electrical system serving a shelter space effects architectural planning through the demands made on space for equipment, relationship of spaces, distribution lines, storage of supplies, access facilities to equipment and related problems of air supply, exhaust, water supply, and drainage.

The amount of power required for normal operation of the

building and convertible shelter area is an engineering problem and is calculated to serve a variety of equipment. Each building must be treated as an individual situation. The inclusion of total air conditioning, for example, will affect the power needs greatly. As a very rough estimate, however, one may use eight kilowatts per one hundred persons for initial shelter planning.[10]

Much of the heavy electrical equipment may be placed outside the building. In designing for low-level blast protection, such items as transformers and switchgear should be located, mounted, and secured to offer the maximum resistance to blast. It is not possible in most cases to place such equipment serving an entire building within a protective shelter because of space limitations, heat disposal requirements, and overall cost. The best one can do is give to the equipment the maximum exterior protection that is economically feasible. Distribution lines, particularly, where they enter the building, may need special consideration, such as providing flexibility at the point of entry.

Depending upon location of primary generation, substations, and transmission lines, the normal power supply from outside sources may be interrupted by blast. In that event, provision for automatic switchover to auxiliary power supply is needed. The switch equipment should be capable of manual operation in case of failure of automatic controls. All such equipment should be placed in a position that is readily accessible, but still protected from accidental damage and from the tinkering of amateurs.

It is desirable, but not always feasible, to install auxiliary power equipment which is capable of operating the shelter to the same degree as the outside power sources. The two general classes of such auxiliary equipment are batteries and engine-generator sets. Batteries to provide power for full operation will require a large storage room. Shelf-life can be extended considerably by using primary cells in which the electrolyte is not introduced until just prior to usage. Conventional wet-cell batteries create hazards related to heat, fumes and acid spillage, and therefore require a ventilated room separated from the occupied space. Silver zinc cells, although more costly, have the advantages of absence of fumes, resistance to shock, and a very minimum of heat generation. These cells will now produce fifty watt-hours per pound of weight.[20] New developments in fuel cells and high current chloride batteries offer considerable advantages for the future. If batteries are used for the auxiliary power source, adequate facilities for charging must be provided.

Generators suited to the needs of shelters fall into two classes: gasoline-powered and diesel-powered. Gasoline powered generators may be either air-cooled or water cooled. Larger capacities up to 170 KW are possible in the water cooled type, but limitation of water supply may rule out this type for shelter use. These generators are relatively lightweight, compact, economical in first cost, operation and maintenance. Remote control operation is commonplace. Diesel powered generators are of the water cooled type only and are available in a wide range of sizes from 10 KW to 230 KW. The fire hazard is less with this type than with the gasoline powered, but starting troubles are greater.

Regardless of the type of auxiliary power system used, the planner should seek and provide the following:

(a) Adequate venting to supply combustion air and to remove heat and obnoxious fumes
(b) Facilities to recharge batteries
(c) Fire-protection facilities to remove the danger of fire and to provide fire-fighting equipment
(d) Equipment capable of starting easily after long, idle standby periods
(e) Adaptability to operation by untrained personnel
(f) Relative insensitivity to shock, through inherent construction and by proper mounting
(g) Capability of operation by remote control
(h) Ease of maintenance, inherent and by virtue of location

Contrasted with auxiliary power sources which are designed and sized to provide full operation within the shelter is the emergency power source which will provide a low level of power for only the most austere operations. These operations may be limited to very low illumination, ventilation, communications, detection and warning devices, and essential medical processes. With these very limited objectives to meet, the power source may be quite small. Batteries or a generator are still the best answers, as they are for full auxiliary power supply.

The location of the private power source requires special attention. It may be placed inside the shelter, adjacent to the shelter or completely separated from the shelter.

Certain advantages are obtained when the power plant is located inside the shelter:

(a) Switching can be manual, remote, or automatic
(b) Control is simple
(c) Malfunctions are quickly discovered
(d) Easy access exists for maintenance and repair
(e) Maintenance personnel are not subjected to outside nuclear radiation
(f) Equipment is sheltered from overpressure and heat

Disadvantages which may exist when the power plant is located inside the shelter:

(a) High noise level
(b) Presence of odors
(c) Danger from such fumes as carbon monoxide
(d) Danger from fire
(e) Exhaust and air supply problems
(f) Use of valuable protected space for equipment, spare parts, oil and fuel (although fuel tanks may be located elsewhere if the entry piping is protected).
(g) Heat problem which reduces efficiency, calls for larger equipment, and possibly damages equipment

When located outside the shelter, the following advantages exist:

(a) Noise within shelter is eliminated
(b) Odor problem is avoided
(c) Efficient heat removal, requiring a smaller system and less fuel
(d) No danger from gases
(e) Valuable shelter space not used
(f) No blast closure valves needed

Disadvantages inherent in this location are:

(a) Equipment must be designed to withstand over-pressure and heat
(b) Possible damage by missiles created by blast
(c) Rupture of transmission lines at point of shelter entry must be guarded against
(d) Corrosion may be a problem
(e) Manual switching is impossible during an attack
(f) Maintenance personnel risk exposure
(g) Decontamination facilities required for re-entry of maintenance personnel.

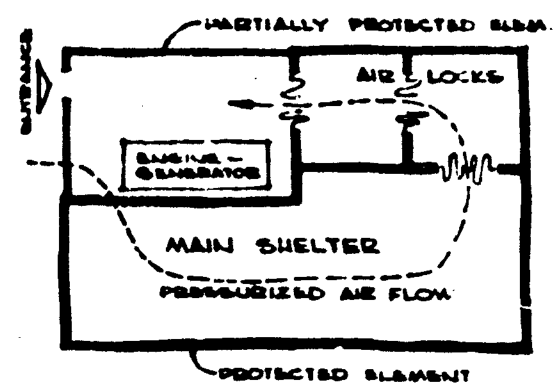
A workable compromise exists when the generation equipment is located in a room adjacent to but not actually in the protected shelter. The equipment can be protected from missiles and debris, and can be partially protected from thermal and nuclear radiation. In this location, most of the advantages of the in-shelter location would be obtained and the disadvantages would be considerably reduced. The diagram shows this compromise location.

At the present time, the logical equipment to provide for either auxiliary or emergency power sources is a conventional system that has been thoroughly tested and found suitable for the particular needs of the shelter. However, research into other energy sources may produce solutions which are far superior to any now available. Some of the other sources which offer promise in the future are:

(a) Thermoelectricity, including thermionic converters using semiconductors, heat or nuclear energy
(b) Solar cell generators
(c) Steam turbines fired by fuel oil or nuclear energy

which operate conventional generators.

No system is any better than its state of readiness and its condition of repair. It is imperative, therefore, that ease of maintenance be kept in mind at all times when locating mechanical and electrical equipment. Accessibility to all parts which might conceivably need attention is a must. Spare parts need to be stored in a convenient place near the equipment, and the inventory must be kept in a complete state at all times. A system of maintenance with clear responsibility and simple records should be set up and strictly enforced. Control of all equipment, material, and spare parts is a part of shelter operations.



COMPROMISE LOCATION OF GENERATOR

Special attention should be given to supply and storage of fuel for engine-generators. Type, size, and location of the storage tanks require consideration of a number of factors, among which are:

(a) Accessibility for filling tanks
(b) Convenience of distribution line from tank to engine
(c) Protection from corrosion
(d) Capacity for at least the planned duration of shelter occupancy
(e) Reasonable protection from shock
(f) Flexibility at entry of line from tank through shelter wall.

If the tank(s) must be located inside the building, these additional precautions are needed:

(a) Venting of space to dissipate fumes
(b) Drains to dispose of fuel in the even of leakage
(c) Proper type fire extinguishers conveniently located outside the tank room

PLANNING FOR SHELTER

Whether one is confronted with the planning of a barracks, a school, an administration building or a hospital, there is a certain order and structure in the planning process. At times, the preliminary planning studies and research become more involved than the actual design. In a space where two entirely different functions (normal and emergency) are to be housed, the problem requires a more thorough analysis than what normally would be the case.

It is not the objective of this guidebook to be a manual for the design of any specific building for normal functions but to give the architectural designer a tool to use in the planning of integrated convertible shelters in general, and specifically, in slected Navy buildings. Since these shelters are to be integrated with the conventional building function, structure, and mechanical systems, it becomes difficult, if not impossible, to segregate protection aspects and conventional planning aspect. Thus the well designed convertible shelter is dependent upon being integrated into the building system at the inception of planning.

In order to visualize the influence that convertible shelter planning has on the conventional design of buildings and related structural and mechanical systems, one will have to consider items which at the time may have no apparent relationship to the convertible shelter problem. The following items have been selected to emphasize the above statement:

Building Shapes
Proportions of Interior Spaces

Corridor Systems
Natural Light and Interior Spaces
Flexibility of Buildings
Materials

Building Shapes

The shape and the volume of the building will evolve from its internal and external functional requirements, circulation and relation of basic spatial elements integrated with the structural and mechanical systems. The integrated convertible shelter is only one of many important elements of the building. Because of its functional requirements it will, to a certain degree, influence the basic building shape. However, it should be stressed that the emergency criteria must not reduce the effectiveness of the normal function. If, during the process of planning, one determines that the most effective building shape from the standpoint of the normal function does not lend itself to inclusion of convertible shelter concept, the concept should be abandoned, for example a greenhouse does not lend itself to the inclusion of convertible shelter. To do otherwise may result in a poor solution for both objectives.

Effective shielding, as discussed above, depends upon both mass thickness and distance. Thus, various building shapes will offer different degrees of protection. It is important to note that there is a positive correlation between the factors that will be required for efficient protection at a minimum additional expense. Such factors may include perimeter of exterior walls, materials, and organization and integration of mechanical systems. Thus the initial cost of material and labor, as well as the maintenance and operating expense, is less in a compact plan with a minimum amount of exterior walls, than in a spread out, rambling scheme. In compact buildings, some difficulty may arise in obtaining adequate isolation or separation of spaces where the normal conventional requirements demand diversed functional elements. A good solution to this problem may partly depend on the use of interior spaces, or double or triple sets of corridors. These considerations will be discussed below. In a multi-story structure the problem of diversification is easier to solve; each floor might give the required isolation of the specific functions.

It should be noted that basements completely below ground without windows will generally offer excellent emergency protection, but they can be considered convertible shelters only if space is useful for normal functions as well.

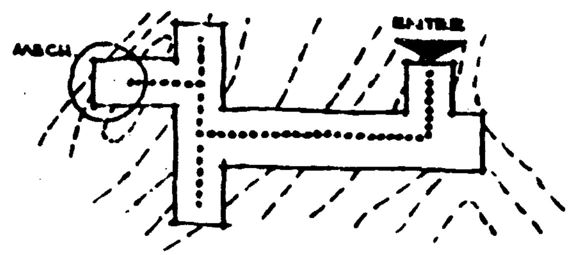
Annotated sketches are introduced through the remainder of this section of the Chapter. These sketches illustrate planning considerations and details regarding good or poor conventional planning principles and their adaptability for convertible shelter use.

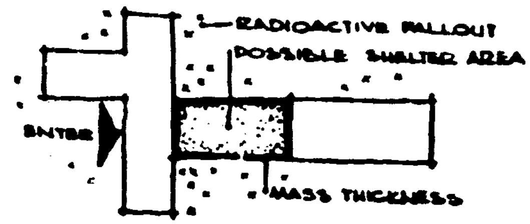
IRREGULAR BUILDING SHAPES

Excessive exterior walls, hence high initial expense of material and labor. Cooling, heating and insulation create high operational expense. Mechanical service lines long and expensive. Circulation complicated. Foundation problems at irregular sites.

Not well suited for integrated convertible shelter because:

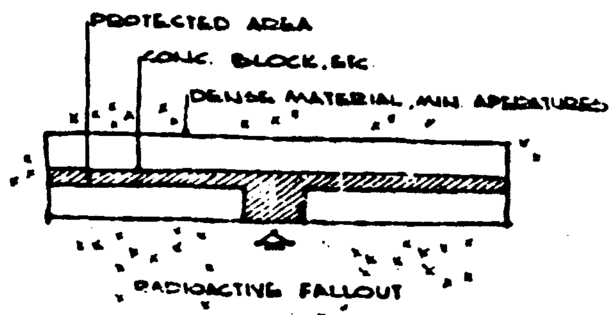
Little depth of building sections
For radiation protection, excessive wall thickness necessary, hence, high expense
Possible solution if portion of basement is designed for dual function.





CONVENTIONAL DOUBLE-LOADED CORRIDOR —
poor to fair protection

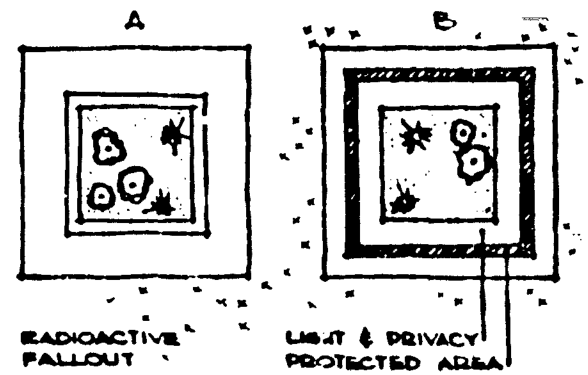
Can be single or multi-story buildings with or without basement. With light weight exterior and interior walls, protection very poor. Concrete block or dense material exterior and interior walls, minimum apertures — fair protection, particularly in multi-story buildings.



INTERIOR COURT SOLUTION — poor to fair protection.

A. Single-loaded corridor with windows: poor protection. Without fenestration, a fair protection.

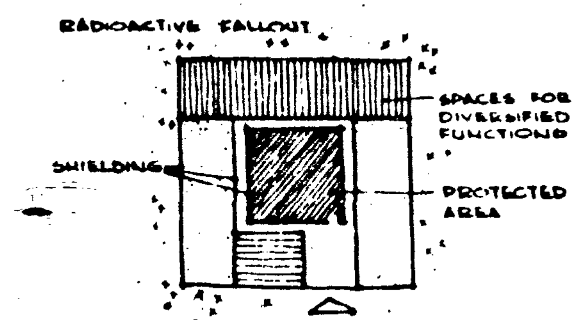
B. Double-loaded corridor, some protection depending upon material.



CORE CONCEPT — good to excellent protection.

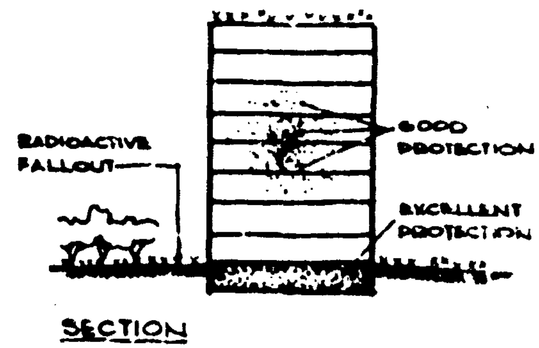
Compact and unified solution. Size of core and corridor system dependent upon building function. Minimum mechanical distribution lines. Inherent structural strength Single or multi-story with or without basements (partial basement possible). Minimum exterior walls, low initial and operating cost.

Emergency protection excellent in interior core, especially in multi-story buildings. Effective shielding by multiple walls (mass), and geometry (distance). Degree of protection dependent upon thickness and density of materials.

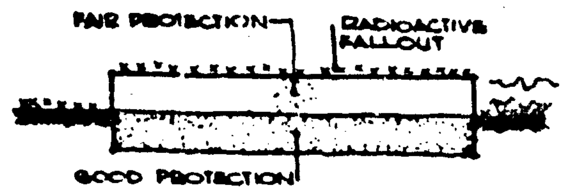


MULTI-STORY BUILDINGS — good to excellent protection

Good protection in middle stories — best protection in basement.

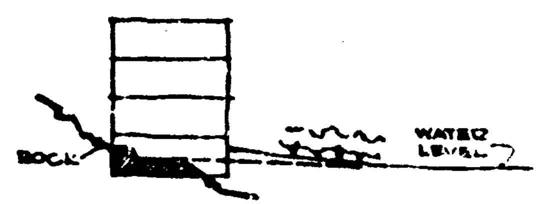


SINGLE STORY BUILDING — poor protection



Full or partial basement fair protection.
Central section of compact building offers fair protection only with thick roof and walls.

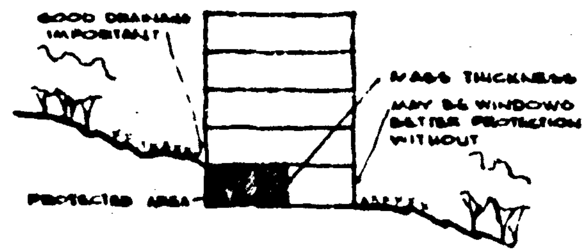
Sometimes sites have a high watertable making a basement solution undesirable. This is a common occurence in many Naval installations. Rock and blasting may eliminate otherwise economical basement solutions. However, where possible, the basement will give very economical space. Toilets, storage of various types, mechanical facilities and specific interior rooms may well be designed as basement spaces if this will improve the overall function of the building for normal as well as shelter use. The type of rooms will be discussed further in Chapters 4 through 9, citing specific military building types.



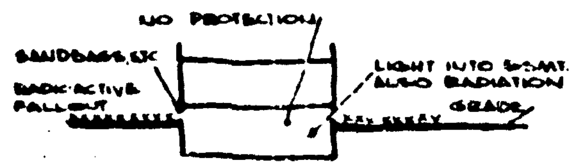
BASEMENT EXPENSIVE AND OF LITTLE USE DUE TO BLASTING AND DRAINAGE

BUILDING ON SLOPED SITE — poor to fair protection

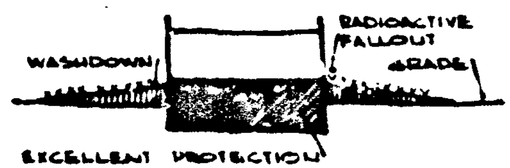
Economical solution. Good normal use of exposed portion of ground floor. Degree of protection dependent upon apertures and thickness of materials of walls, and floor above.



Partly exposed basement with windows habitable spaces for various functions. May convert to good shelter if unprotected areas are closed with sandbags, heavy shutters, etc



Partly exposed basement. Excavation material used as back fill. Economical. Excellent protection if multi-story building. Paved surface sloping away from building provides possibility of wash down of radioactive fallout.



Proportions of Interior Spaces

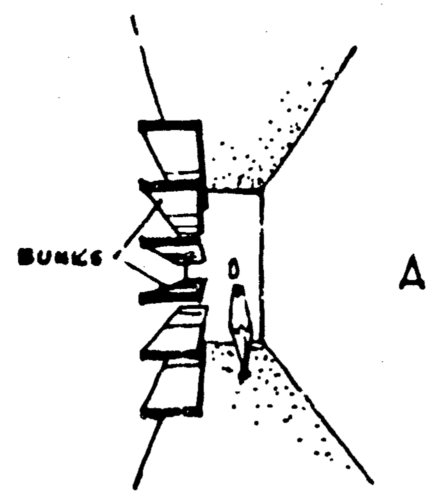
The design of space is in general, the art of enclosing and/or combining spaces for a specific functional environment. The architectural form is the creative expression of purpose, material, and construction. Historically, new materials have allowed for new construction methods and new construction methods combined with the function have allowed for new space conception. Architectural planning of spaces, however, is not dependent upon an isolated element. Well assigned single or dual function spaces must be integrated with structural as well as mechanical systems. In a building designed with integrated convertible shelter, a new function is introduced whereby the spaces must be planned for convertibility and flexibility. The shelter requirements must not unduly influence the spaces for day to day function. A building is primarily designed for the normal use; the convertible shelter becomes a secondary function.

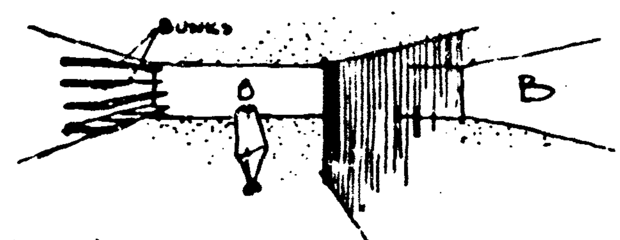
Although the proportions of rooms have no direct relationship to convertible shelter design, indirectly they will influence shelter planning and configuration.

The effect of room proportions on shelter configurations:

A. Has more bunk space per square foot than B

B. Has more usable floor area and more possibility of subdivision of space than A





Corridor Systems

Corridors effect the convertible shelter directly only as a protected area useful for shelter space. Indirectly the corridor serves as a means of ingress and egress to the convertible shelter area and a a circulation space between shelter spaces. Many types of corridors are adaptable to convertible shelters, depending on the building shape, and type of materials. Corridors have an advantage over many other spaces inasmuch as they at all times are uncluttered and free of furniture (other spaces may have to be cleared for effective shelter use). The corridor space also usually has the advantage of having direct access to auxiliary rooms that may be necessary for shelter function, such as, general storage, food storage, toilets, and mechanical equipment rooms.

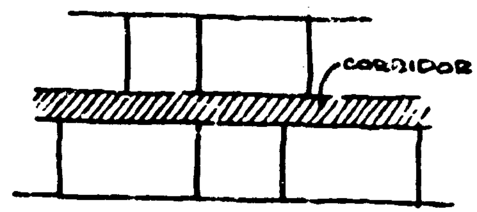
Like building shapes and proportions of rooms and spaces, the proper corridor dimensions are the result of good functional planning. At times it might be valid to increase the corridor width to give better opportunity for use of space for the emergency function. It will provide inexpensive convertible shelter space. In the process of planning and design, corridors often tend to become too long and narrow. A five to six foot wide corridor might be adequate for a sizty to eighty foot length, but not if the space becomes a continuous 200 to 300 foot tunnel. As the traffic load increases, the corridor will have to be wider.

Generally corridors can be classified as:

1. The double loaded central corridor
2. The single loaded corridor (with or without natural light)
3. The multiple corridor network

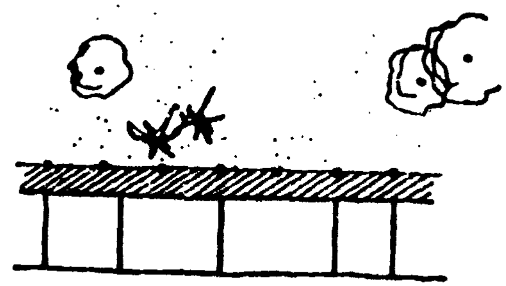
These corridors will be discussed briefly as they relate to buildings in general and convertible shelter in particular. The corridors offer various degrees of protection depending upon the materials used and also on the location in the building.

THE DOUBLE LOADED CENTRAL CORRIDOR



Efficient and low cost corridor layout. With proper materials and minimum apertures in exterior and interior walls, corridor useful for convertible shelter. Bunk arrangement depends upon corridor width and height. Toilet and storage facilities adjacent.

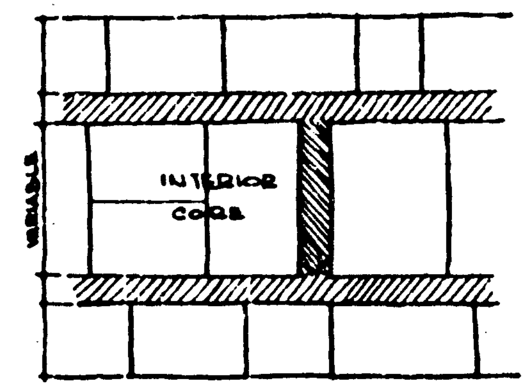
THE SINGLE LOADED CORRIDOR



Expensive, longer traffic lines. Window wall provides light and view, corridor useless as a shelter. If corridor walls are enclosed, some protection anticipated, depending on apertures in other walls, and materials.

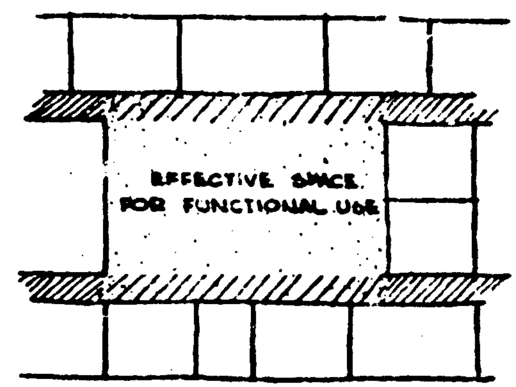
THE MULTIPLE CORRIDOR NETWORK

System requires laterals for cross traffic. Wide interior core for economy. System will contribute to shorter building perimeter hence less total expense. Network provides excellent possibilities for convertible shelter in core. Corridors may also be used for shelter, although protection factor greatly reduced.



VARIATION OF THE DOUBLE CORRIDOR NETWORK

Example of efficient use of corridor as part of a multi-purpose space. Good to excellent shelter space particularly in multi-story buildings. Dependent on mass thickness of interior and exterior walls and number of apertures. If high protection, wall thicknesses become excessive and solution costly.



Natural Light and Interior Spaces

The following discussion will attempt to provide answers to one of the basic requirements with regard to the integrated convertible shelter. The admittance of sun and natural light may be desirable or a nuisance depending on the functional requirements and the design.

Daylight can provide good and inexpensive illumination for general purpose and overall lighting; if direct sun is controlled. There are, however, often considerable expense and difficulties involved in solving the sun control problem. This control can be achieved in various ways:

(1) All northern exposure
(2) An adjustable or permanent control device integrated with the building (set back of window walls, overhang, louvres, or special glass)
(3) Interior curtains, screens, or blinds. This is often a substitute solution where the control has not been planned on an integrated basis.

Frequently daylight, controlled or not, has to be supplemented by artificial illumination to provide adequate working conditions. In our current technology there would actually be no need for windows to provide light and fresh air. One can substitute the natural environment by a controlled environment giving an even healthy temperature and ventilation and with more efficient illumination in any kind of weather on a year-round basis. A decreased amount of window area will also reduce the heating expenses in the winter and cooling expenses in the summer.

Why then windows?

Why should one have to encounter so many problems that are difficult and expensive to solve when a mere closing of the envelope or rather omitting the windows would apparently solve the problems? Why does not one design buildings with entirely enclosed spaces? Although many people are in favor of complete enclosed and artificial environments for work, the idea is not widely accepted. Psychologically many people find it revolting to even think about being sealed in without contact with natural light and nature, especially in spaces of a constant and long term occupancy. On the other hand what do people see of nature in an automobile factory on the assembly line?

Many rooms will obviously serve and function better as interior spaces for various reasons. Why should one have disturbing light in rooms for visual aids, TV, or the like, and, why should not toilets and corridors be designed for artificial ventilation? Why should not many types of rooms as classrooms or conference rooms in schools, treatment, utility, and operating rooms in hospitals, and recreation or common areas in barracks be enclosed spaces away from noise and distractions? One can conclude that in

most types of buildings, there are rooms that can serve their intended function and be more efficient as interior spaces due to:

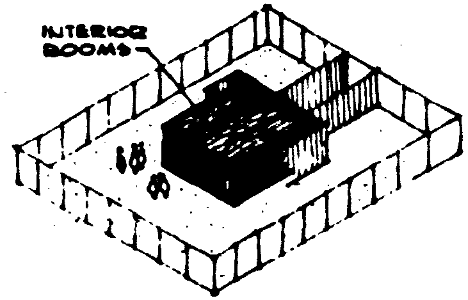
(1) Better environmental control
(2) Short time occupancy
(3) A combination of both

In this general discussion one cannot pinpoint any specific room or space; it will be necessary to analyze the specific needs and functions for each individual building type. The question will arise: where can or should these spaces be located? The answer will depend upon a number of factors: the type of building, the structural and mechanical considerations, the number of spaces that will serve better as interior environment for normal functions and the relation of these spaces internally and externally. In the planning of integrated convertible shelter the location of these spaces is critical. In addition to being enclosed by as much mass as possible, and by maintaining a maximum distance from the radiation source, the various spaces should be grouped. Thus the organization of the spaces can be divided into three basic concepts:

(1) Complete interior core
(2) Central section of building
(3) Specific section of building

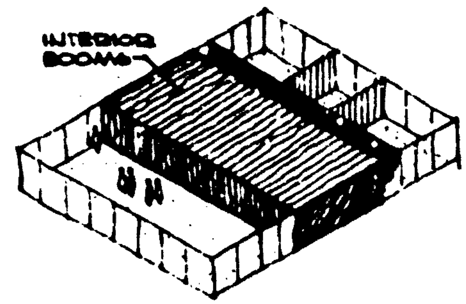
Variation of these three concepts may include a core within the core or the extreme case of a completely windowless building. Except for special building types, this latter concept would not be a practical approach under normal conditions. In the design of an artificial environment, it is important to create a variation of the spatial qualities, as well as variation and contrast of light. Also, the intensity and brightness of color should be keyed to the various functional spaces.

THE COMPLETE INTERIOR CORE



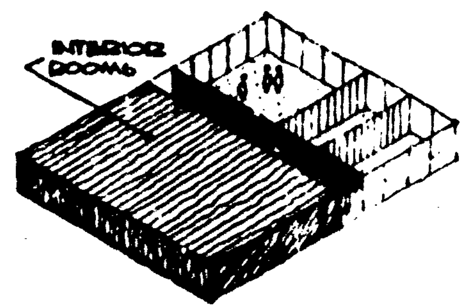
Size of core is dependent upon the requirement of interior rooms for normal functions. Can give excellent protection depending on materials, and height of building. Can also be developed into a core within a core concept for excellent protection. Concentration of mechanical systems. Good circulation. Exterior wall available for spaces requiring natural light and ventilation.

CENTRAL SECTION OF BUILDING



A solution if the need for interior environment increases. Good protection, dependent upon the density and thickness of materials on end walls.

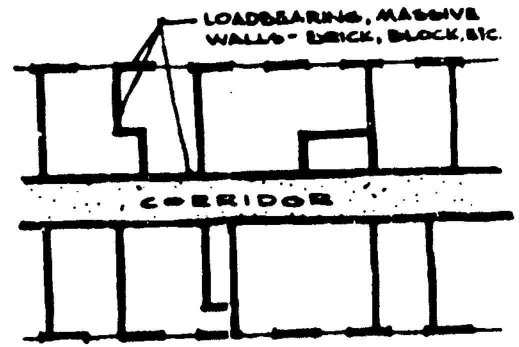
SPECIFIC SECTION OF BUILDING



A solution if maximum space required for interior use. Protection dependent upon material in three exterior walls. Considerable added expense. Not a desirable solution.

Flexibility

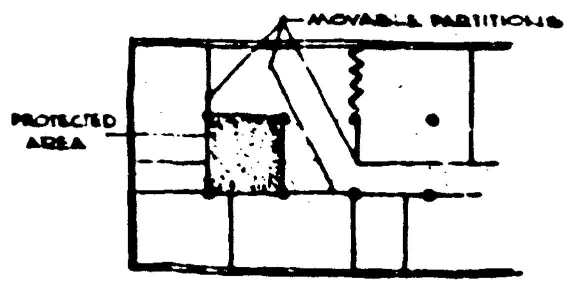
The changing functional requirements in various types of buildings at times demands a certain degree of flexibility in the internal space arrangement, as well as an expansion of the total space. This demand is becoming increasingly more frequent in todays architecture and the flexibility ranges from the moving of a few walls to the total change of the internal environment. Generally the light, prefabricated movable partition has been the answer to this problem. These partitions should satisfy specific requirements as noise control, durability, and methods of attachment in order to offer efficiency. The introduction of the integrated convertible shelter adds a restriction to the amount of flexibility. Thus the "old" fixed plan solutions, where interior room partitions as well as the exterior walls were heavy-load bearing masses, have a much greater protection potential than the large open space subdivided with the light movable panels. This does not mean that the emergency protection will exclude the important factor of flexibility. It means, however, that certain sacrifices must be evaluated on the drawing board at the planning stage in order to determine a satisfactory solution for protection and flexibility. Since the degree of protection depends upon mass and distance, it becomes apparent that a certain amount of flexibility may have to be sacrificed. There will still remain specific areas both in which flexibility exists within and without the fixed section.



NO FLEXIBILITY

No flexibility possible unless major construction changes. Contemporary demands for flexibility of spaces not satisfied.

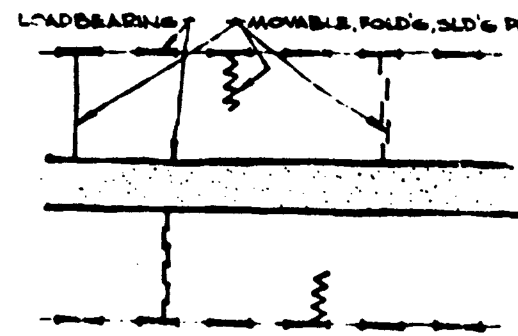
Inherent protection factor possible without added material.



MAXIMUM FLEXIBILITY

This scheme utilizes load-bearing exterior walls only, or a column and slab construction with curtain walls. All interior walls of light movable panels. No protection.

Fair protection possible with protective core introduced within shell. Protection dependent upon mass thickness in walls and/or position on middle floors in multi-story building.



THE INTERMEDIATE SOLUTIONS

Loadbearing walls paralle to exterior walls — fair protection in corridor, depending upon apertures. Flexibility restricted to spaces between corridor walls and exterior walls.

Movable walls such as movable, folding or sliding partitions, little protection value—large amount of flexibility retained. Many variations and combinations of concept possible.

Mechanical sub-systems (heating, cooling, ventilation, plumbing, and electrical) will add restrictions to the flexibility in any building. However, the degree of restriction will change with the building type; obviously the Hospital, Subsistence Building or the Communications Building with the complex mechanical distribution systems, will offer less flexibility than the Administration Building, the School, or the Barracks. The organization and integration of these systems will greatly effect the flexibility.

In the planning one should not only consider internal flexibility, but also future flexibility (expansion). Normally, expansion will not effect the convertible shelter planning directly. However, often the shelter is designed to protect the occupants of the building as initially planned. Then if the building capacity increases, one must also consider expansion of the shelter or provide for addition of convertible shelter. The normal function requirements can be brought out of balance due to the expansion to specific parts of the building. This may cause poor function and an overload on certain elements. It might therefore be necessary during the initial planning stage to design certain units or spaces to satisfy future planning requirements. The value of flexibility in planning becomes even more important when one is concerned with a definitive scheme rather than the conventional "custom" designed building. Since the topography, soil conditions, orientation, and adjacent buildings vary, a definitive scheme must be designed with enough flexibility to insure adequate adaptability to the local conditions. When integrated convertible shelter is included in a building, even though there are many local variables, and regardless of the variable local conditions, a definitive scheme must be designed in such a way that the convertible shelter can be included without jeopardizing the normal function.

Materials

The selection of materials for a building normally is dependent upon:

(1) Protection from natural elements
(2) Sub-division of spaces and functional requirements
(3) Geographical location— availability and durability of material
(4) Inherent structural strength
(5) Climatic conditions
(6) Local architectural expression — tradition
(7) Cost of local vs. imported labor and materials

The materials used for the division fo space must have varied qualities such as: resiliency, acoustical properties (absorption and transmission), cost (initial and maintenance), function, and esthetics. The factors mentioned are all important in the design of any building in order to arrive at a solution that is a sound, architectural expression.

With the introduction of convertible shelter requirements one is also introducing a factor effecting the selection of materials. Mass thickness or density

and thickness of walls (exterior and interior) floors and roofs are of prime importance in shelter design. A two inch thick, light weight wall panel would offer little protection while a ten inch reinforced concrete wall would give considerably better protection. This does not mean, however, that all walls in a building designed for a convertible shelter need to meet the mass thickness requirement. It becomes a part of the basic planning to design the shelter spaces in such a way to allow a certain freedom of choice of material both for economy and for architectural expression. Low level blast protection also becomes a determining factor in the selection of material. In order to design a building with well integrated convertible shelter, it becomes essential to evaluate the materials to be used from both the normal and emergency functional requirements.

ILLUSTRATIVE SOLUTIONS

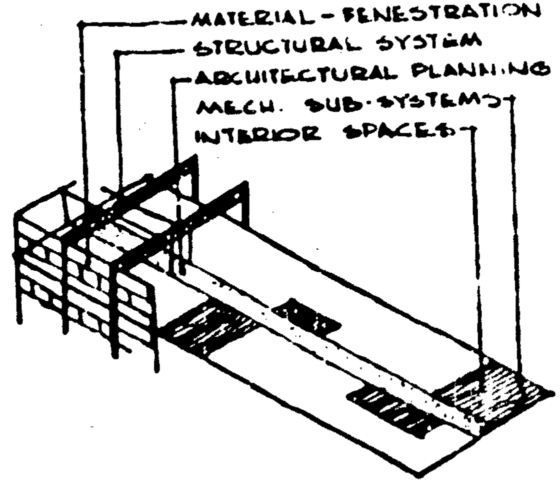
LOCATION OF SHELTER SPACE

In order to further develop an understanding of the philosophy of integrated shelters, a series of sketches and comments illustrating the approach to the planning of such shelters are presented.

"TYPICAL" CONVENTIONAL PLAN

Architectural, structural and mechanical aspects designed for normal environment. Interior spaces arranged to satisfy functional requirements. Spaces and circulation vary with building function.

Convertible shelter not considered in planning. Possible shelter spaces too scattered for effective use.

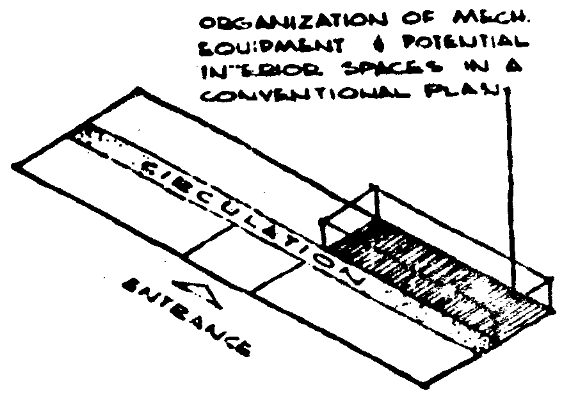


CONVENTIONAL PLAN WITH CONCENTRATION OF POTENTIAL INTERIOR SPACES.

Possible solution in many building types, but interior spaces do not have effective location, need not be located on exterior walls when windows are not required.

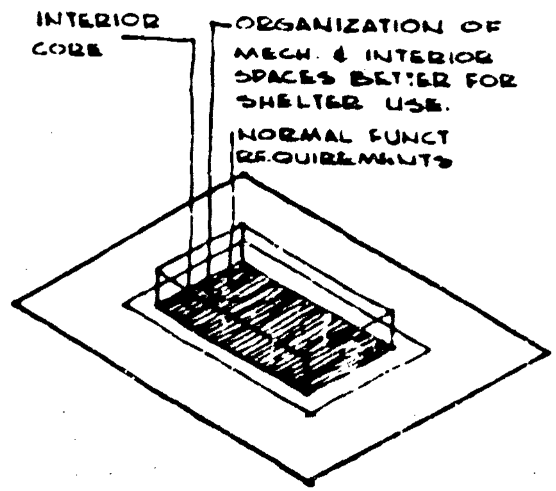
Forced internal solution may create problem in exterior architectural expression. Mechanical equipment can be included in these interior spaces.

Interior space useful for shelter, but excessive and expensive wall thicknesses required for adequate protection. Investigate for more effective location of these interior spaces.



EFFECTIVE INTERIOR SPACE – NORMAL AND EMERGENCY

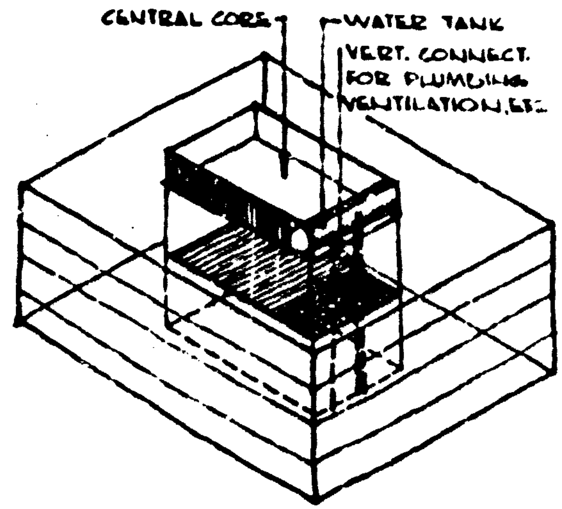
Central location, concentration of mechanical sub-systems (sanitation, ventilation, and electrical), good circulation, inherent shielding, roof shielding poor for one story building.



LOCATION OF INTERIOR SPACES IN MULTI-STORY BUILDING

Shielding improved — geometry effect considered. Integration of environmental engineering elements for emergency function: water source, sanitation, air, and power.

Note: Basement areas may be good solutions, depending upon local land conditions.



MATERIAL SELECTION — INHERENT SHIELDING AT MINIMUM EXPENSE

Mass thickness of material considered.
Inherent low level blast protection dependent on integration of material and structural system.

__Wall A__

Apertures according to functional and environmental requirements, kept to a minimum. Greater material thicknesses required for Walls B and C if panel wall used.

__Wall B__

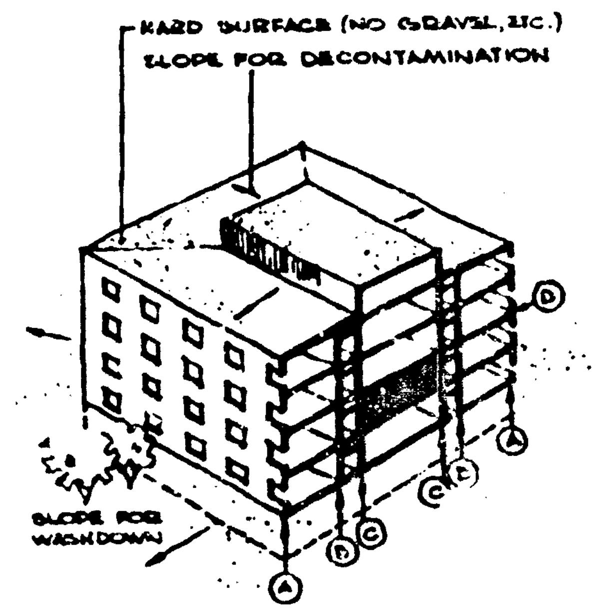
Minimum area of apertures, mass of material selected important. Baffling of apertures desirable.

__Wall C__

Maximum material density and thickness necessary. Minimum apertures. For compatible and economical solutions Walls A-B-C should be considered concurrently. Wall C shortest perimeter of material—maximum shielding at minimum expense.

__Ceiling D__

Maximum mass considered. Extra shielding may be necessary due to roof contribution (especially in low buildings of 1, 2, and 3 stories.)

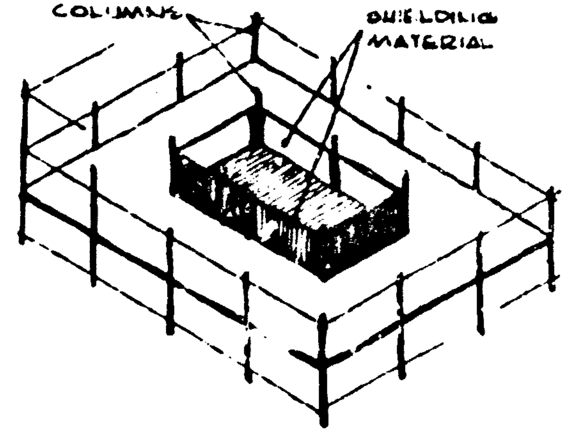


SECTION OF BUILDING

STRUCTURAL SYSTEMS INTEGRATION

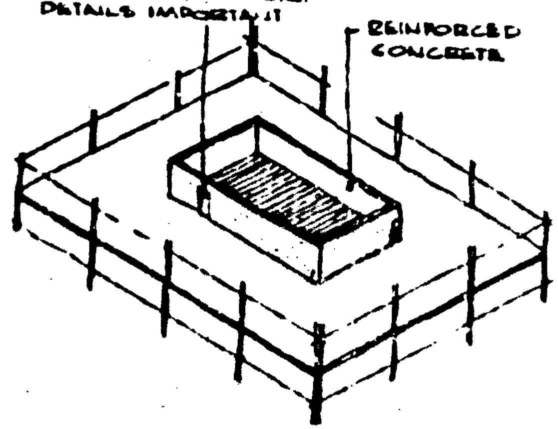
Example

Columns with girders and slab or flat slab.
For effective radiation shielding fill in between columns with dense material. Poor low level blast protection — materials and structure not integrated — minimum lateral strength. Other structural considerations important.



Example

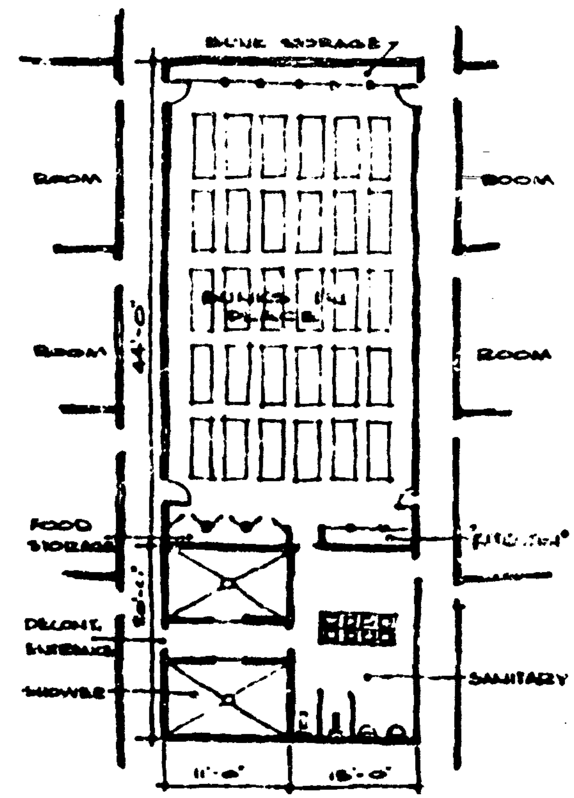
Basic structural system as above.
Material itself integrated part of the structure, and not "hung on" for shielding protection only. Essential in central core, but may be considered in other parts of building. Hinges, locks, doors, material, and construction details of apertures important for low level overpressure exclusion.



INTERIOR SHELTER SYSTEMS

Using the requirements developed plus the influence of the local conditions, it is possible to determine an interior shelter configuration. Consider an interior space, consisting of two adjacent rooms, such as that illustrated below. The large space under normal circumstances could serve as a lounge, classroom, or office, and the small space is normally used as a toilet. Modifications of the normal building facilities should be kept to a minimum. In this case only the addition of one door into the shower, the building of storage areas at either end of the large rooms, and the provision for potable water storage are necessary to provide a workable shelter. The door to the shower room would remain locked until the emergency situation requires its use. At this time the shower room away from the food storage wall could become a room for contaminated articles. This space could also serve to store waste until such time as it is possible to move the waste out of the shelter area. The toilet room continues its function as a sanitary area and also serves as an intermediate control point before entry into the shelter proper.

The number of toilets per person should be determined on the basis of normal requirements—if the toilet space and number of toilets do not prove adequate for shelter use, chemical toilets should be provided. It is also possible to install cabinets on one wall of this space in which may be kept tools and other equipment necessary to maintain the shelter in operating conditions. The "kitchen" is located at the west end of the shelter for obvious reasons.



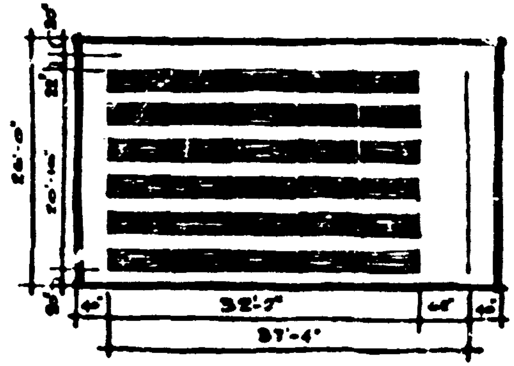
The closet type arrangement can be easily controlled both during shelter stay and under normal conditions. After the shelter is in use and the bunks set up, this space may be utilized by the shelterees for personal storage.

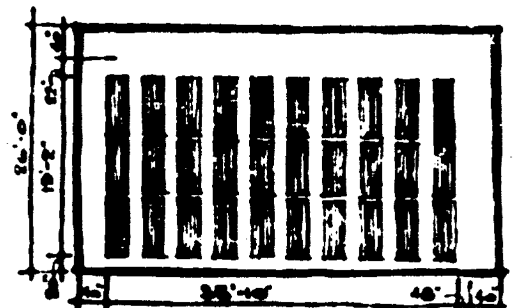
Considering circulation, it seems that in order to provide shelter for a maximum number, one must sacrifice some facility of movement. With the bunks oriented length wise, circulation is facilitated toward the service areas, however, a person must pass a maximum number of bunks to arrive at one end of the room or the other.

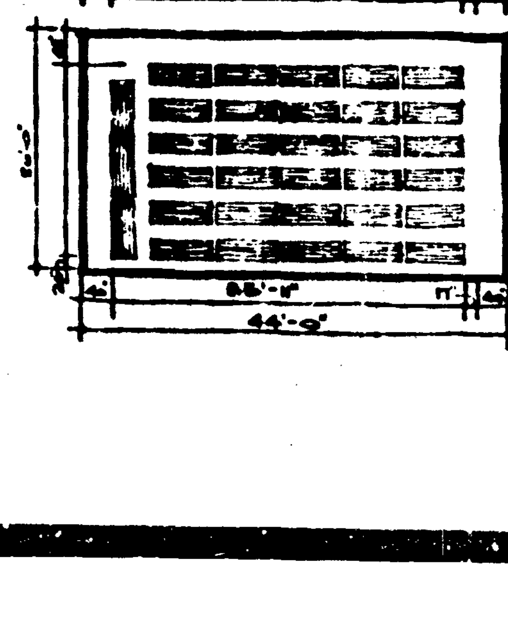
With the bunks oriented in the short direction circulation toward the service areas is not as direct, yet less bunks are passed and one is able to use less restricted aisle space.

As an example, consider the number of bunks which may be located within the space available—it is found that by placing the bunks lengthwise the number of bunks are limited to a row of five in length and six in depth if the limits of 20 inch passage and 40 inch aisle are used.

If the bunks are run in the short direction, it is possible to locate three in a row with ten rows; however, this gives the same number of bunk stacks as those run in the other direction. It now becomes a question of what space is left over and what bunk system can best utilize it. From inspecting the two alternatives it would seem that the first system which leaves an extra five foot, two inches at the service end of the shelter is the most efficient. This area plus the forty inches established as necessary aisle space provides a total of eight foot, six inches which may be utilized as "open"







space. This space may also be utilized to accept three more bunk stacks if it is considered necessary. The latter set of bunks would run the opposite direction to the main bunk system and because of this, should be placed at the storage wall and in order to avoid interference with circulation toward the service end.

To determine the storage space required for sustenance, the necessary factors to consider are: the type of diet; the number of people to be sheltered; and the estimated length of stay.

Example:

30 bunk stacks
3 bunks high

Food storage space for a shelter population of 90 persons with a requirement of 0.2 cu. ft. storage space per person per day assuming 14 days, totals 252 cubic feet.

Water storage space required for a shelter with the same capacity and staytime (assuming 2 quarts of potable water per person per day) totals 630 gallons—84 cubic feet.

On the basis of the above example, it is apparent that it is desirable to consider the planning of the integrated convertible shelter space at the time of the initial planning for normal use.

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PART TWO : APPLICATIONS

Part Two, Applications consists of a series of analyses and concept developments of integrated convertible shelter in six selected military building types. Each succeeding chapter contains one building type. For each building type a series of integrated concepts are developed. The number of concepts developed is not a limitation of the number of concepts which might be developed if additional study were conducted. Similarly, there are many other building types which were not included in the guidebook in which integrated convertible shelter is practicable.

It should be emphasized that the concepts developed are not intended to serve as "definitive drawings" or "complete preliminary design studies" of the various military building types. The concepts are included to illustrate, by example, many of the basic concepts developed in Part One of the Guidebook; hence, serve as stimulus to the planner of many typical military buildings.

The specific building types included in Part Two are:

Enlisted Men's Barracks	100 Bed Hospital
Training School	Subsistance Building
Administration Building	Communications Building

CHAPTER FOUR ENLISTED MEN'S BARRACKS

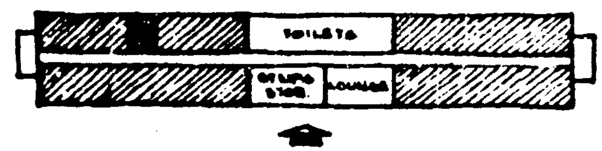
ANALYSIS

CONVENTIONAL REQUIREMENTS

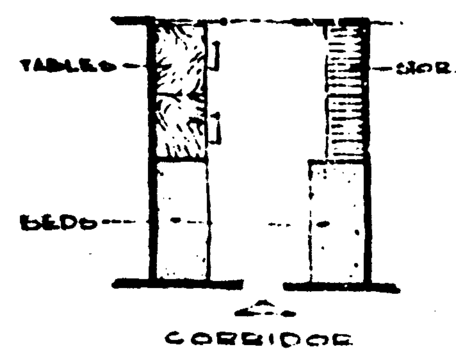
The conventional enlisted men's barracks are two and three story central corridor units designed for 116 and 152 men respectively. The typical floor plan and room arrangement are shown in sketches. The rooms are located off the central corridor and have a dimension of 11 feet by 13 feet totaling 143 square feet, (72 square feet per person). The standard equipment provided in each room is: 2 beds, 2 storage closets, 2 tables and 2 chairs. Main vertical circulation is in the center of the building unit with fire stairs at each end. Toilets, lounge, storage and laundry are located centrally in the block. The barracks are planned without basement, and the materials and construction may vary depending upon the geographical location.

SHELTER CONVERTIBILITY

The conventional plan has very limited possibilities with regard to protection and convertibility of spaces. This plan would give no protection in any space adjacent to exterior walls. Corridors may give some protection in the middle floor of the three story unit if minor changes are made. Some of these changes may be: reducing window areas; baffling of doors, windows, entrances and other openings; and considering mass thickness in the selection of materials.



TYPICAL 1ST FLOOR LAYOUT
2ND & 3RD FLOOR SIMILAR



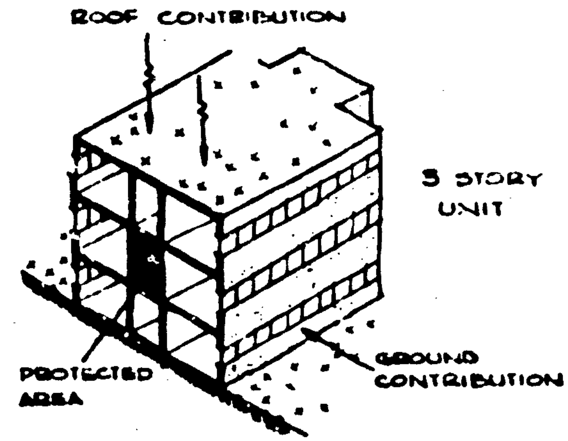
TYPICAL DOUBLE ROOM LAYOUT

This would, however, only give adequate protection for low level radiation and/or short time occupancy. Any realistic degree of protection can only be achieved through considerable modifications and complete planning changes.

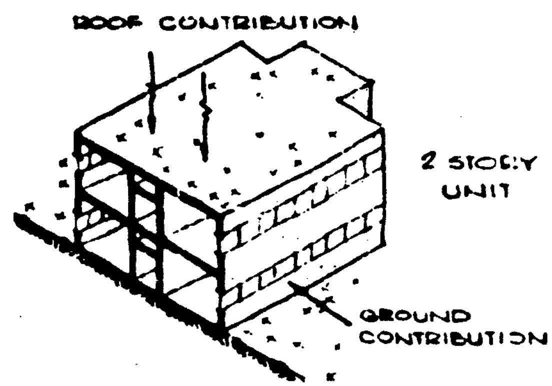
The two story conventional building type will hardly be worth consideration. The first floor will receive considerable ground radiation and the upper floor will be subject to excessive radiation through the roof.

One may thus conclude that conventional plans cannot meet the requirements for effective shielding and should not be considered for convertible shelter.

It will, however, be necessary to study and analyze the existing normal requirements in order to arrive at basic factors determining the adaptability of barracks for the convertible shelter principle.



SOME PROTECTION
WITH MODIFICATIONS



POOR PROTECTION

GENERAL PHILOSOPHY

During the planning process for both normal and emergency functions it is important to keep in mind that one is dealing with military personnel — men in good physical condition, one sex, generally one age group, and under military command.

The men that occupy the barrack will mainly be at the Naval Station for:

(a) Training School (basic)
(b) Boot Camp
(c) Special Training
(d) Normal Support Activities

The barracks environment should provide a functional space and atmosphere for such off-duty activities as:

(1) Rest (sleeping) and relaxation
(2) Writing
(3) Reading
(4) Group activities

The function of the enlisted men's barracks is rather simple compared to other building types in the Navy Base, and thus there will be considerable flexibility in the basic planning and concepts.

Architectural analysis of these spaces will only be considered to the extent they will effect convertible shelter planning.

In addition to being designed for a dual function, many factors must be considered in the planning of these barracks — economy of erection and maintenance, privacy, morale, functional environment, noise, ventilation, and odor control.

For the activities listed above specific space allocations are as follows:

(1) Rooms, cubicles, or open dormitory layout
(2) Common areas and/or lounges for various types of activities and recreation
(3) Entrance, vestibule and lobby necessary for proper function
(4) Toilets, showers, laundry, storage

Regardless of space organization, the existing conventional floor area is being used as a figure for comparison and as basic criteria for the concept solutions:

Room requirement 72 sq. ft. per person	3600 sq. ft.
Toilets, corridors, stairs, dayroom, etc.	3000 sq. ft.
Total space requirements per floor	6600 sq. ft.

Before these spaces can be discussed further with relation to normal function, interior spaces, emergency functions and convertibility, it will be necessary to analyze the various barracks planning systems.

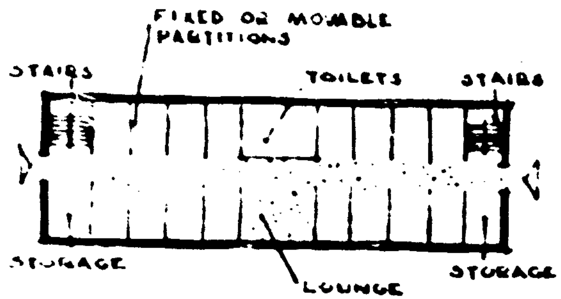
Basically the barracks can be divided into the following systems:

(a) The double room arrangement
(b) The dormitory layout
(c) Single cubicle layout
(d) Variations

These types all have certain advantages and disadvantages; some of these will be discussed briefly below.

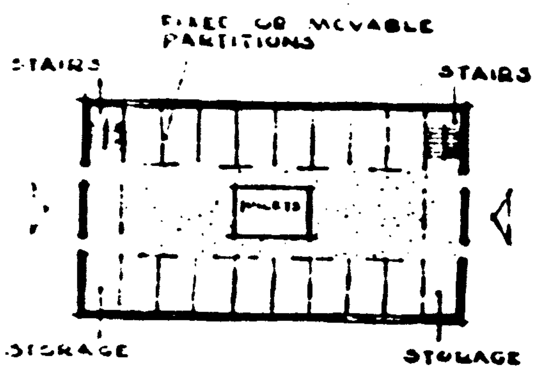
Double Room

An example of this type is the existing conventional plan. Without determining any specific room sizes, this type calls for a relatively large two man rooms since they open from a central corridor. The spaces available for recreational activities are rather inadequate, even with the spacious double room. However, an increase of the lounges or common areas would involve higher cost unless the total building area is kept constant. Control of heat, ventilation and noise is no problem in this plan. The conventional plan is only one of the solutions of this general type, a great variation of schemes would fall under this category.



EXAMPLE 1

GENERAL OPEN BARRACKS PLAN



EXAMPLE 2

COMBINED CIRCULATION SPACE AND COMMON ACTIVITY AREA

Open Barracks—spaces with multiple occupancy (3 or more)

This barracks system requires less area per person, fewer fixed partitions, hence greater economy of construction. The maintenance, however, may be somewhat higher, since wear and tear is not necessarily the responsibility of any one person but a larger group. Other disadvantages will be: lack of privacy, noise and light control; and control of ventilation and odor.

The subdivision of the space varies from the use of light, movable partitions giving a great degree of flexibility to a system with fixed partitions and semi-enclosed cubicles. Regardless of space dividers, the "open barracks" generally will have little or no corridor as such, but rather a multiple-use open circulation space.

Single Cubical or Rooms

This type gives advantages not apparent in the other types, notably privacy for the individual as well as creating maximum space for common activities. The individual space requirement can be kept to a maximum and the "excess" space can thus be utilized for the enlargement of the common areas. As the individual spaces will not be occupied any extended length of time except for sleeping, compact individual units can be justified.

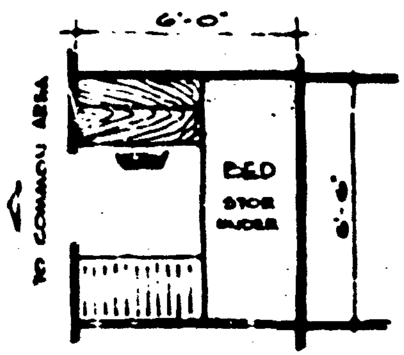
The following analysis will provide one approach to the method of achieving larger common activity areas without increasing the total area. To explain this, and for the purpose of comparison, it is necessary to use the figures from the conventional barracks plan:

Double room area			72 sq. ft. per person
Part of corridor			8 sq. ft. per person
Total space requirement			80 sq. ft. per person

Assuming the space requirement in a one-man cubicle is:

bunk	3' x 6 1/2'	=	19 1/2 sq. ft.
desk	2' x 3'	=	6 sq. ft.
closet	2' x 3'	=	6 sq. ft.
total		=	31 1/2 sq. ft.
		use	32 sq. ft.

plus 8 square feet of circulation space equals 40 square feet per person

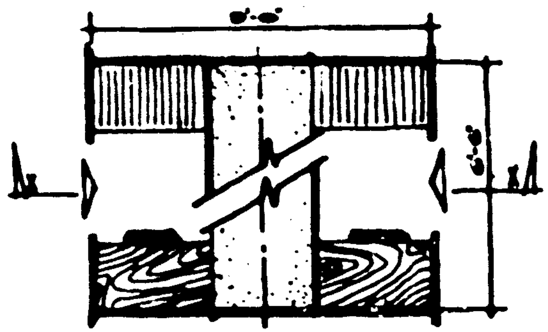


TYPICAL CUBICLE UNIT

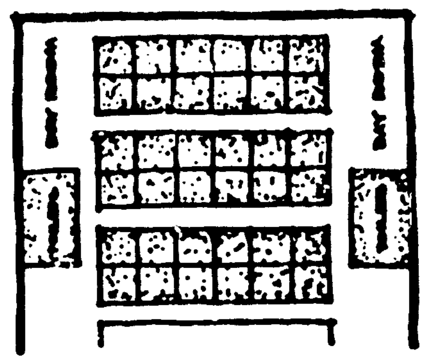
Using the above 80 square feet per person and the cubicle area being 40 square feet per person, 40 square feet per person may be contributed to the common acticity area. The initial cost may be higher in this barrack type, but there are definite assets such as noise and odor control, privacy for the individual, and opportunity to design larger common activity areas.

This 40 square feet per person cubicle space can be decreased to 30 square feet per person by utilizing a special bunk arrangement. The 10 square feet "saved" can thus be added to other areas where enlarged spaces are more desirable. This particular bunk solution does not lend itself to the provision of natural light into the cubicles without decreasing the flexibility of the planning as a whole.

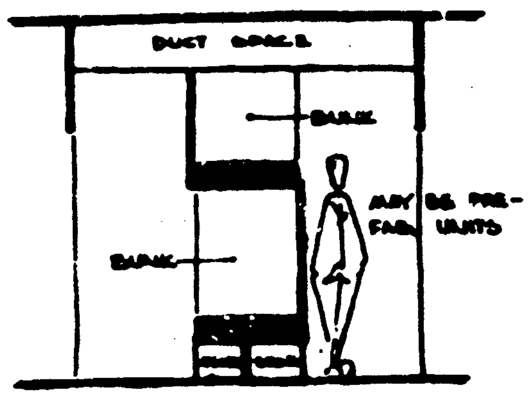
Another scheme utilizing similar bunk arrangement, but a modified layout and a larger area per person can be planned with windows in each cubicle, provided that the cubicle be located along the outside walls. Based on the capacity of 50 men per floor this solution may not be too desirable since it may have a tendency to result in a proportion of the total building not well suited for convertible shelter.



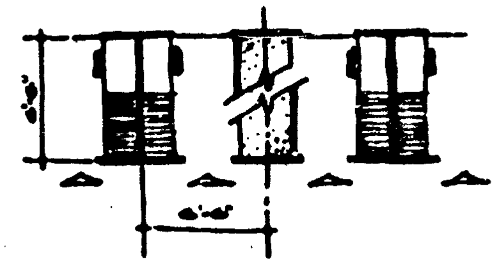
PLAN



SCHEME WITHOUT WINDOWS



SECTION X-X



POSSIBLE WINDOW SOLUTION

Variations

In addition to these barrack types, a great number of combinations and modifications exist. An example can be shown by the possible modification of the double room plan. This could take the form of a two to four man cubicle or room scheme. In order to obtain larger common activity areas, the cubicles should be designed as compactly as possible. Whether there are two or four men assigned to a cubicle, a bunk arrangement will be necessary.

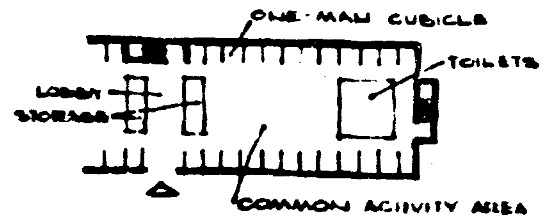
Regardless of design scheme, the objective is to achieve the ultimate in usable functional environment and a minimum of wasted space.

As one is concerned with integrated convertible shelter planning, it also becomes a necessity to arrive at a scheme that will conform to the planning principles of convertible shelters.

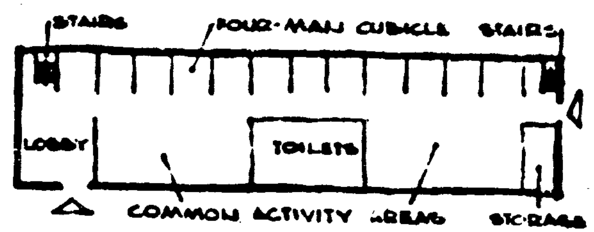
Before any approach to design concepts is attempted, it is necessary to investigate the individual spaces and their convertibility or adaptability to the function of protection and emergency requirements.

Some factors affecting these spaces are:

(1) Interior spaces — area and relationship
(2) The degree of flexibility for shelter use
(3) Fixed and movable equipment
(4) General shelter requirements
(shielding and other survival items)



EXAMPLE - SINGLE ROOM PLAN



EXAMPLE - DOUBLE ROOM PLAN

EXAMPLES OF ARRANGEMENTS OF FOUR-MAN CUBICLES

The most important factor in relation to architectural planning is item (1) above — interior spaces. Most of the barrack activities would take place during evening and night hours, since nearly all daytime would be occupied by duty assignments away from the barracks. With the exception of Saturdays and Sundays, it is assumed that most study and free time activity would take place in the "dark hours" and the value of natural light and view thus becomes rather insignificant. Also, many rooms would function better without natural light and with a controlled environment (T.V., toilets, etc).

Then judging from the above, one may conclude that it is possible to have all spaces as interior environment, it is however desirable to keep rooms or cubicles with windows since these spaces may otherwise appear to be rather cramped and enclosed. The degree of flexibility in the various spaces depends upon the conventional use, the amount of heavy and fixed furniture, and mechanical equipment. An interior space with a high protection factor would not serve well as convertible shelter unless the space can be utilized almost instantaneously and efficiently as emergency space.

SPACE ANALYSIS

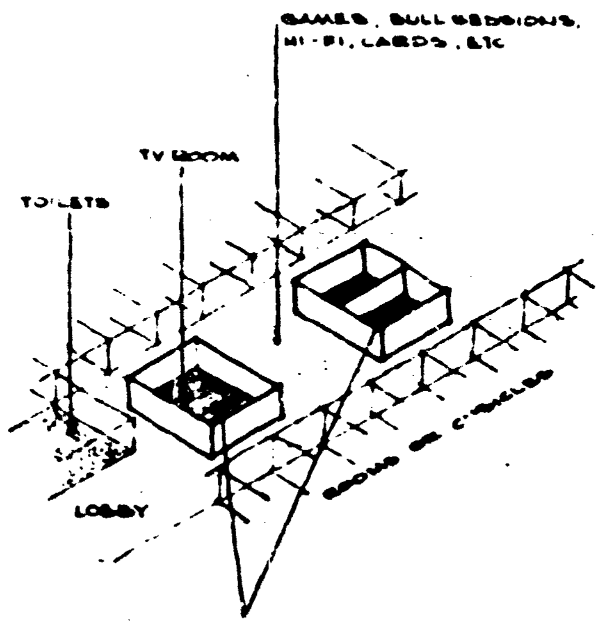
Sleeping Space

Sleeping Space is basically used for rest and study, and therefore requires a certain amount of privacy. As mentioned above, these spaces can be small and compact with the standard equipment only, and they will have some shelter adaptability if they are planned as an interior space. Ventilation and noise control are important factors in the planning of these spaces. Whether they are designed as interior spaces or along an outside wall, circulation and relation to entrance, toilets and common activity area is of great importance for smooth normal operation. To achieve good shielding, one may consider these rooms to serve as a barrier between outside and interior.

Lounges and Common Activity Areas

The lounges and/or common areas are spaces for group activities. Important planning criteria for these spaces are: (1) Central location (convenient to toilet facilities); (2) Privacy for TV grouping, card playing, radio, and bull sessions; (3) acoustical characteristics (noise control); (4) relaxing atmosphere by color and textures; (5) lighting; (6) ventilation; and (7) equipment layout.

As noted, the common areas will be subject to a considerable variation of activities, and these activities may require different environments. One should thus in the planning attempt to achieve as large a space, or spaces, as possible and considerable flexibility. Subdivision of space with acoustical control may be desirable in order to cope with



EXCELLENT PROTECTION
(DEPENDING UPON MATERIALS)

LOUNGE AREA (CORE)

the high noise level from some activities. Since TV is becoming increasingly popular, there could be one TV room on each floor. If one large space should function as a multi-purpose room, some men are going to sacrifice their group activity for a TV or radio audience. Consequently, there should be additional rooms or spaces not being used for TV to give the desired flexibility. To provide effective noise control, mass is needed. Since mass also is essential for effective shelter these spaces can be considered as emergency areas with high protection within the general convertible shelter space. Furniture should give no problem to the convertibility since it is light in weight and relatively movable. The common activity areas assumed to be interior spaces and well related to entrance, toilets (decontamination facilities), and being a rather spacious subdivided space, may serve well as a convertible shelter. At least one common space (lobby) should be easily accessible from the outside to take care of short time transient activities and visitors. Some storage area should be provided for normal use as well as emergency equipment and supplies.

Toilet Rooms

The toilet rooms (including showers) should be planned at a central location to minimize walking distance. Divided toilet rooms (two adjoining as in the conventional scheme) are better than one single large room, because one room can be temporarily closed off for cleaning or maintenance, and thus providing

less confusion. The centralization of these toilet rooms contributes toward simplified plumbing layout and greater economy. In certain cases, where the building is very long or where it proves to be difficult to arrive at a central location, a decentralization of the toilets may be desirable but more expensive.

Toilet facilities will function better based on 100 per cent artificial ventilation and light. The number of fixtures should generally be based on the requirements prescribed in "Basic Mechanical Engineering. NAVDOCKS, TP-TE-4" and are as follows:

Water Closets	10 to 12 persons per closet
Urinals	16 to 18 persons per urinal
Shower	16 to 19 persons per shower
Lavatories	8 to 9 persons per lavatory

These figures are somewhat lower than the existing conventional plan requirements.

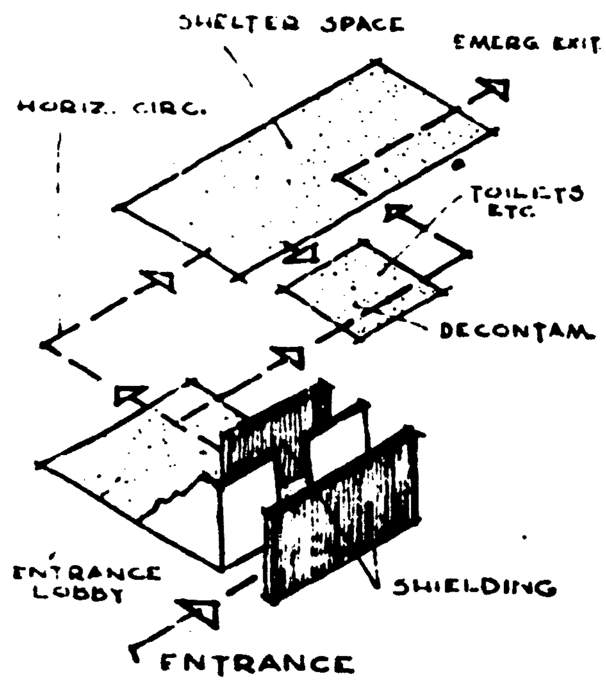
Sanitary facilities are a basic requirement in shelter spaces: they should be planned to function both under normal and emergency conditions. In the enlisted men's barracks the ratio of men per fixture for normal function is well over the required ratio for survival conditions and thus the sanitary facilities will be satisfactory for emergency situations. However, stand by equipment, such as chemical toilets and buckets, must be provided in the case of failure of the general water supply. In addition to storage facilities for both potable and non-potable water, there must be provision for storage of other emergency fixtures and equipment related to sanitary functions. Decontamination facilities should preferably be integrated into this area. The planned shower facilities for normal use may also, with minor modification, serve as decontamination space. Thus the toilet room should be planned with convertible shelter in mind in order to design integrated entranceway and decontamination facilities without additional cost.

Laundry facilities, and cleaning gear, should also be incorporated in the "wet" areas to cut plumbing cost.

Stairs, vestibule, lobby, and circulation space depend greatly upon the shape and layout of the total building. These elements must be designed for both normal and emergency functions since they are essential for smooth operation. In the overall planning, care must be taken to prevent breaches in the shielding and thus jeopardize protection. Permanent baffling might be necessary, but this can become an integrated part of the design. Likewise emergency closing devices may at some point be necessary for sealing off the protected area.

Mechanical Equipment Rooms

Mechanical Equipment Rooms should also be an integrated part of the building and not a parasite Central location will shorten the distribution lines and prevent excessive loss of heat and lower both the initial and the operating costs. Complete air - con-



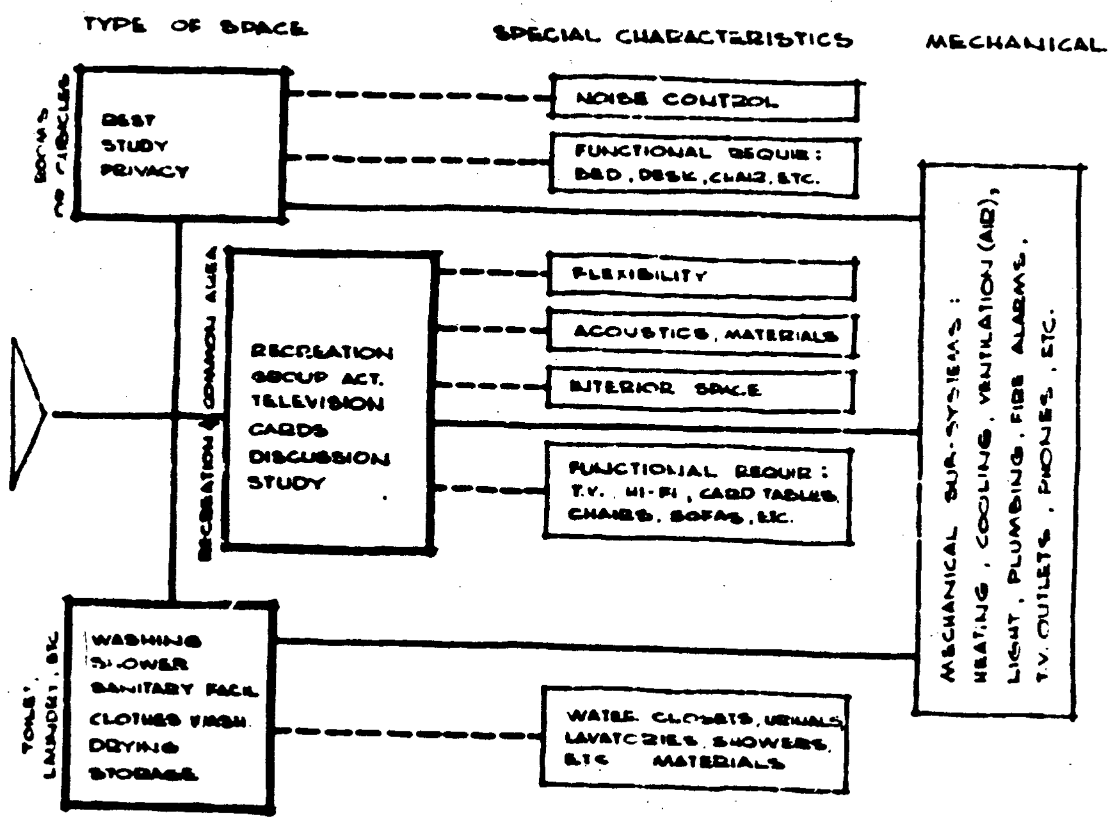
NORMAL AND EMERGENCY FUNCTIONS

ditioning may be expensive, but worthy of consideration in warm, humid climate and for interior spaces as well. Any interior space must be provided with an adequate ventilation system.

Stand-by emergency power supply, effective shielding of air intakes, and exhaust vents should be considered. Regardless of the amount and detail of the mechanical equipment, it is important to provide shielding and access to these spaces so that any emergency repair can be undertaken without hazard since operation during emergency situation generally would be a requirement. The space for the mechanical equipment should preferably have an interior location. The use of this space for general shelter area may be considered in certain cases.

<u>Summary</u>

The various types of spaces which are a part of the enlisted men's barracks, the various specific requirements for design, and the mechanical considerations are summarized in schematic form illustrated on the next page.



TYPE OF SPACE
SPECIAL CHARACTERISTICS
MECHANICAL
ROOMS OR CUBICLES
REST
STUDY
PRIVACY
NOISE CONTROL
FUNCTIONAL REQUIR: BED, DESK, CHAIR, ETC.
RECREATION & COMMON AREA
RECREATION
GROUP ACT.
TELEVISION
CARDS
DISCUSSION
STUDY
FLEXIBILITY
ACOUSTICS, MATERIALS
INTERIOR SPACE
FUNCTIONAL REQUIR: T.V., HI-FI, CARD TABLES, CHAIRS, SOFAS, ETC.
TOILET, LAUNDRY, ETC.
WASHING
SHOWER
SANITARY FACIL.
CLOTHES WASH.
DRYING
STORAGE
WATER CLOSETS, URINALS, LAVATORIES, SHOWERS, ETC. MATERIALS
MECHANICAL SUB-SYSTEMS:
HEATING, COOLING, VENTILATION (AIR),
LIGHT, PLUMBING, FIRE ALARMS,
T.V. OUTLETS, PHONES, ETC.

INTEGRATED SHELTER CONCEPTS

CONCEPT I

Space for 50 to 53 men each floor. Preferably three or more floors. Two men to each space—four men to a unit. Total area per person as in conventional scheme (6500 square feet per floor).

Protection factor in areas D_1 and D_2 will vary depending upon material selection and type of door arrangement. Various door arrangements to individual spaces are:

A Standard solid core doors to each 2 man space
B No doors but sliding panel of good shielding material
C One single standard solid core door to each 4 man unit
D No doors

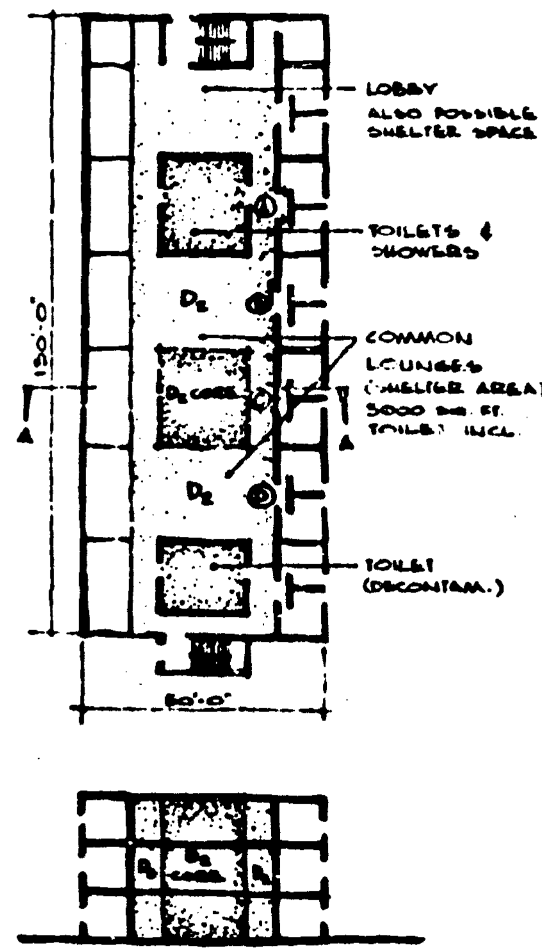
Decontamination facilities in toilet area. Emergency stairs and exits can be entrance to protected area. Normal entrance can also be used as an entrance to protected areas if proper shielding is planned.

Advantages

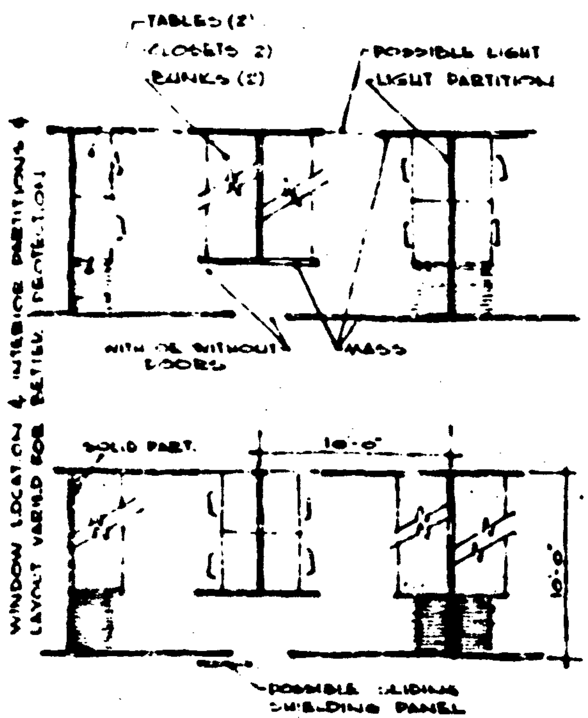
Large common area and shelter spaces; middle core within shelter area can be used for radio, and TV due to high noise insulation value; good circulation and little waste of space; centralized toilets; variety of interior spaces; natural light in rooms.

Disadvantages

Lack of privacy for the individual; poor control of heating and cooling in concepts utilizing door arrangements B and D; noise control may be difficult for the same reasons, however, control is better than for open barracks type.



SECTION A-A



CONCEPT 1

CONCEPT 2

General Solution

Modified open barracks layout, with unit subdivision of space, 48 men to each floor. Preferably three or more floors. Total area each floor - 7000 square feet as compared to 6500 square feet in conventional scheme.

Unit subdivisions treated as an open cubicle layout. Organization and dimensions in cubicles variable (see sketch A and B on the next page).

A - 10 feet by 10 feet open cubicle gives a good planning module but lack of privacy in each cubicle. Too much circulation through the space.

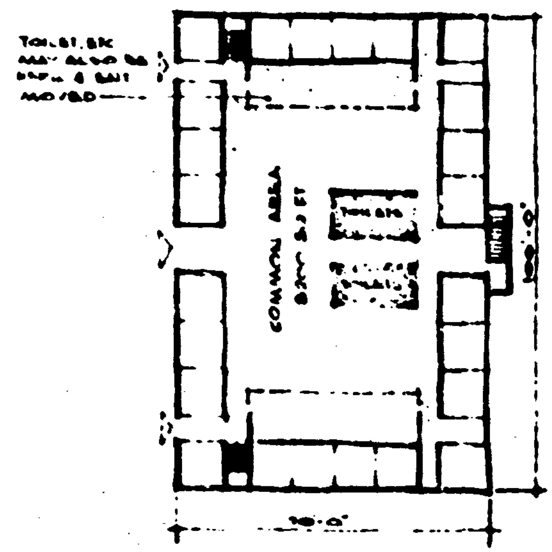
B - 12 feet by 5 feet open cubicle will give more privacy in cubicles inasmuch as bunks and work spaces have been separated from general traffic area.

Advantages

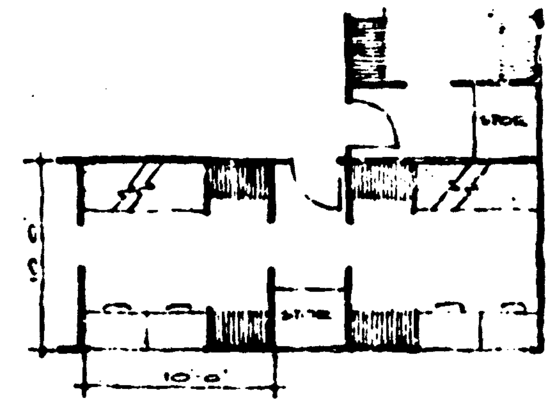
More privacy as compared to open barrack scheme. Large common area plus 3200 square feet may be subdivided into smaller spaces. General protection good to excellent, depending on material selection and the detailed design of a core within the shelter area. Also possibly less expensive than Concept 1 due to less shielding material and doors. Variation of planning module possible. Little waste of space, no corridors.

Disadvantages

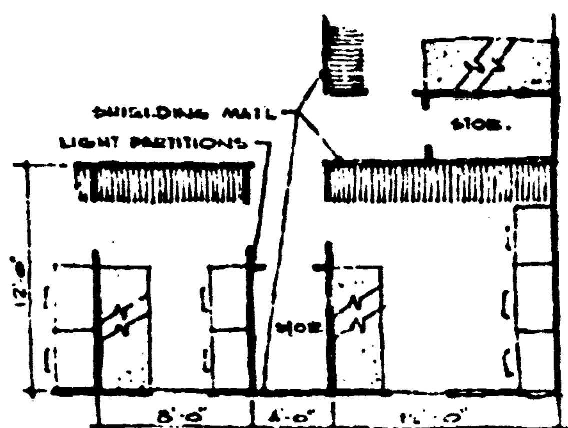
Less privacy than in Concept 1; little control of noise, heating, and cooling, doors needed for each unit for privacy.



CONCEPT 2



A. 10' x 10' OPEN CUBICLE LAYOUT



B. 12' x 8' OPEN CUBICLE LAYOUT

CONCEPT 3

General Solution

Space for 48 men on each floor, one man cubicles, minimum space per person — maximum amount of common area. Total 6600 to 7000 square feet.

Advantages

A - Little defined corridor space and a large common area. Possible with prefabricated partitions between cubicles. Only two stairs necessary.

B - Same as A, but less common area. If interior wall receives adequate mass thickness, fair inherent protection is achieved.

Toilet and storage — good location in both A and B.

Disadvantages

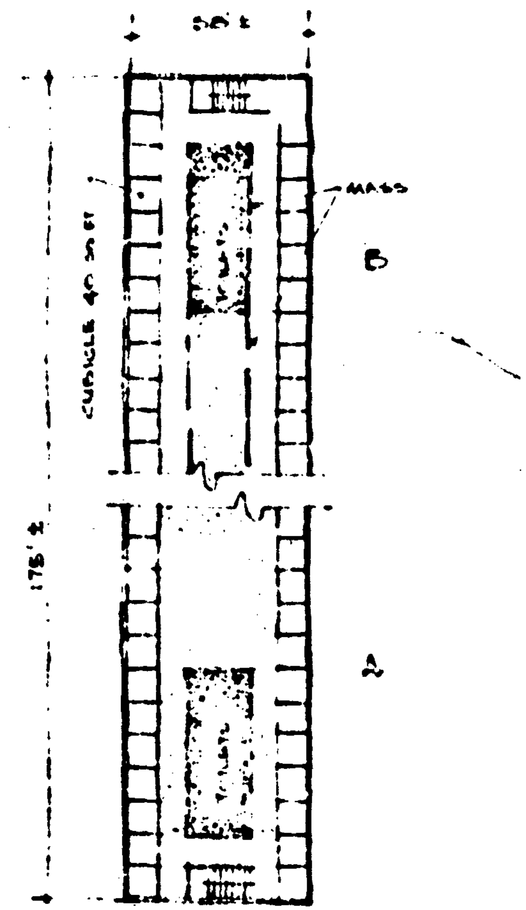
A - Poor shielding. Will require expensive window and and door shielding plus mass thickness in walls.

B - Shelter area smaller. Corridors too long, compared to total floor area.

In order to keep area down and the common area within useful proportions building becomes long and narrow.

Conclusion

Single cubicle concept feasible only if planned for artificial environment.



CONCEPT 4

General Solution

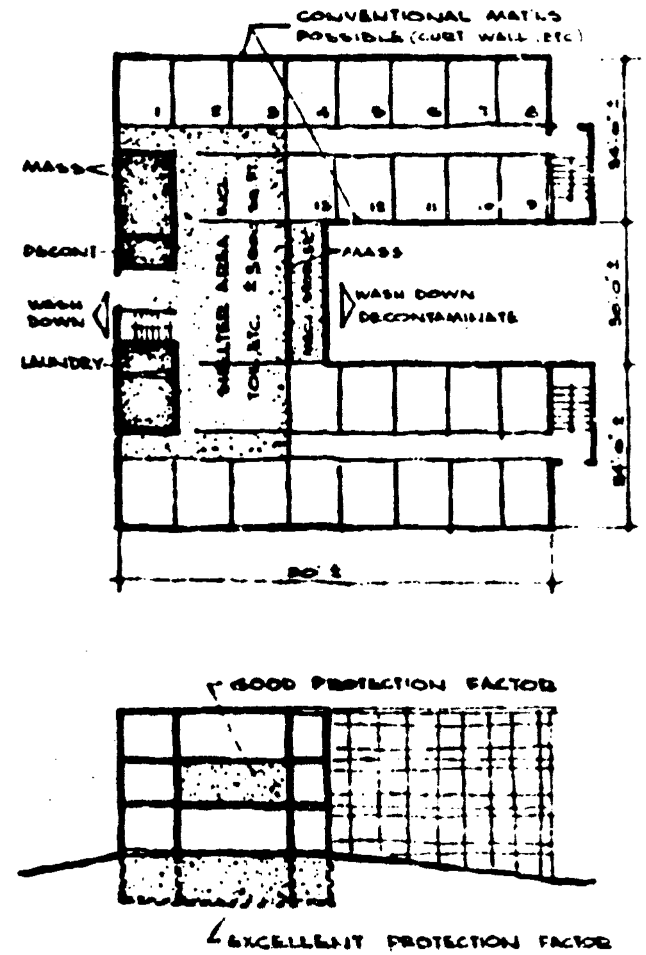
Space for 52 men on each floor, 26 double rooms. Variation of conventional scheme. Room organization the same. Preferably three or more floors 7000 square feet per floor (depending on length and width of the common area).

Advantages

Larger common area than conventional scheme. Good flexibility of common space. Possible to retain the existing double room concept and still have good to excellent shelter.

Disadvantages

Some cost increase due to larger area and more exterior walls. Other disadvantages of the double room scheme have been discussed above.



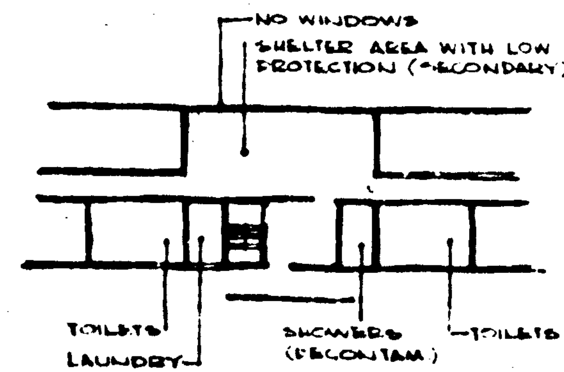
CONCEPT 5

General Solution

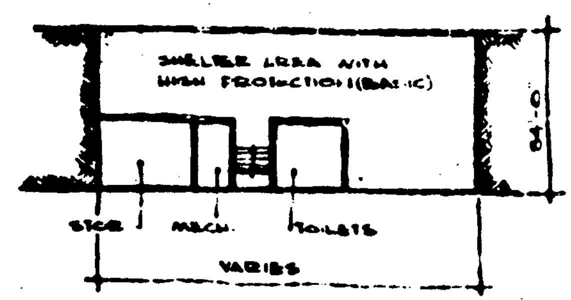
Modified conventional plan with partial basement for recreation area and shelter. (Basement solution in any type of plan will give shelter with high protection factor).

With basement total building area will increase. Basement will provide effective recreation space at relatively low cost provided no drainage and/or excavation difficulties exist.

Slight modifications of upper floor may provide secondary shelter space with moderate protection. May be useful for shelter expansion — modulating shelter after the first few days.



1st, 2nd, & 3rd FLOORS



PARTIAL BASEMENT
(DEPENDENT ON SHELTER CAPACITY)

A N A L Y S I S

CONVENTIONAL REQUIREMENTS

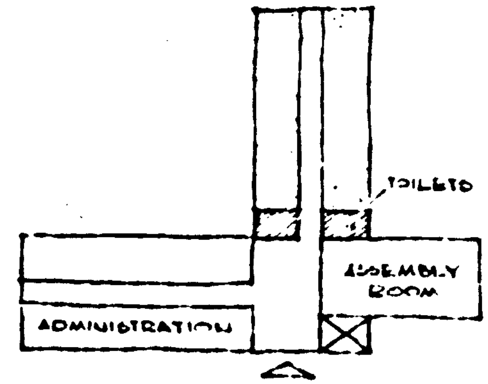
The training school is designed as a two-story, L-shaped structure with a central corridor system.

The entrance lobby is located at the intersection of the two wings. An optional assembly room with a seating capacity of 250 is directly accessible from this lobby and a small platform stage is planned at one end of the room. Administration, library, and mechanical equipment spaces occupy one complete wing on the first floor along with classrooms on the second floor. The other wings have classrooms on both floors.

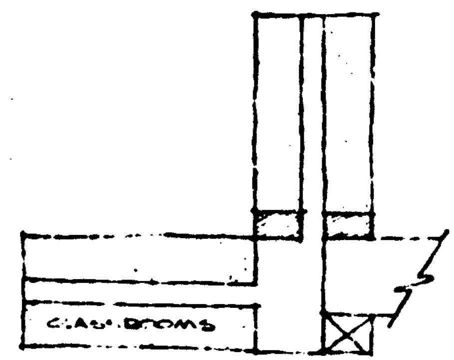
The total area including mechanical and assembly room is 36,000 square feet.

Basic space requirements:

12 classrooms - each	850 sq. ft.
5 classrooms - each	630 sq. ft.
Conference room	560 sq. ft.
Library	900 sq. ft.
Mechanical	575 sq. ft.
Main lobby and entrance cloak room	1300 sq. ft.
Reception room	270 sq. ft.
2 administrative offices, each	575 sq. ft.
Executive office	290 sq. ft.
Commanding officer (C.O.)	350 sq. ft.
General toilet, each floor	290 sq. ft.

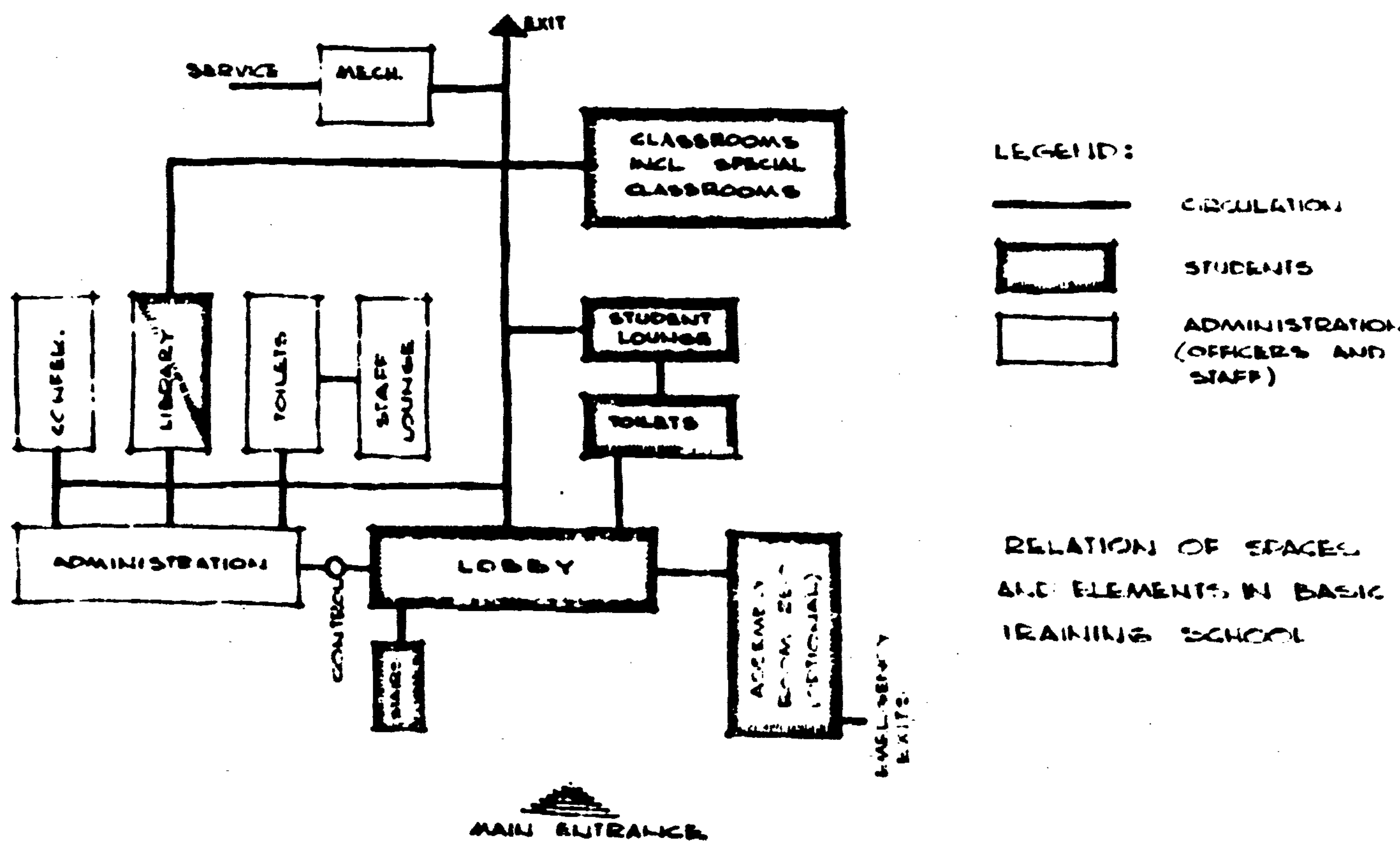


FIRST FLOOR



SECOND FLOOR

EXISTING PROTOTYPE



RELATION OF SPACES AND ELEMENTS IN BASIC TRAINING SCHOOL

Women's toilet and rest room	290 sq. ft.
Staff toilets	290 sq. ft.
Storage space	1200 sq. ft.
Optional assembly room	2300 sq. ft.
Crew's lounge	650 sq. ft.
Instructor's lounge	360 sq. ft.
Control rooms	210 sq. ft.

The Training School is designed without basement and the materials and construction may vary depending upon the geographical location of the building.

SHELTER CONVERTIBILITY

The conventional two story plan does not lend itself to convertible shelter without modifications. This is due to the openess in planning, narrow wings, and the two story height —all factors that contribute toward poor protection. The protection can, however, be somewhat improved by specific changes, such as reducing window areas, baffling of doors, windows, entrances and other openings, and consideration mass thickness and density in the selection of building materials. With these modifications, a low level protection can be anticipated in specifically suited spaces, but cannot be considered adequate for protection against radiation and low level blast for the tolerance levels stated in Chapter 3. Thus, the conventional plan with modifications can only be considered as shelter for low radiation intensity for a short period of time, unless a basement is introduced in the plan. Furthermore, the conventional plan as such cannot be considered adaptable for convertible shelter since the basic principles have not been an integrated part of the planning process.

Any realistic degree of protection can only be achieved through complete planning changes. It will, however, be necessary to study and analyze the existing normal requirements in order to arrive at basic factors determining the adaptability of the Training School to the convertible shelter principle.

GENERAL PHILOSOPHY

The planning of a U.S. Navy Training School is basically no different from the design of any other type of school. However, in addition to the general building criteria, there are several factors that should be taken into consideration.

Flexibility of construction:

(a) Structural simplicity
(b) Adjustment to site conditions
(c) Exposure
(d) Expansion

Flexibility of operation:

(a) Number of students
(b) Subjects being taught (special classrooms)
(c) Versatility of spaces
(d) Materials for function and maintenance

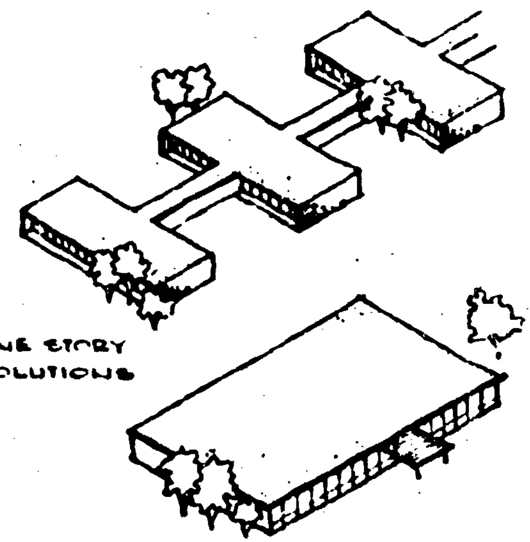
In addition to these rather obvious factors, the shelter convertibility introduces additional requirements. Much literature on school buildings of various types has been published. It therefore serves no purpose to study and analyze the

various factors of normal requirements unless the specific function of convertible shelter requires particular attention and/or the Naval Training School introduces unusual problems. There are a number of basic layouts of school buildings ranging from a one-story type (campus plan, finger plan, cluster plan, loft plan,) to the variety of the multistory building types. One type may be as efficient as another, depending on the site, size and capacity of school, type of teaching methods, and economy.

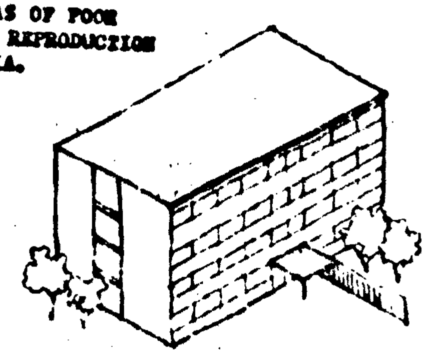
The low, one-story building seems, however, to be a rather unsatisfactory solution to a prototype Naval Training School. Furthermore, the characteristics of this building type without basement do not conform to the basic principles of convertible shelter.

The compact multistory building (three or more stories) can give a better answer to both the normal functional requirements of the Naval Training School and the convertible shelter. The building does not, however, have to take the form of a rectangle or a square, but this shape will, as a rule, offer the best protection in the interior spaces as well as being less expensive. The "compact" multistory building plan will normally give better flexibility as to various site conditions and exposure. Whether a compact plan should be considered with or without basement depends on the functional utilization of these spaces, soil conditions, and water table. The basement in a multistory building can give excellent protection and provide effective and economical spaces for "interior functions." The definite advantages of a compact plan concept can thus not be overlooked are:

(1) Shelter convertibility (effective protection at less



ONE STORY SOLUTIONS



MULTISTORY

expense
(2) Minimum perimeter of exterior walls (economy)
(3) Centralization of mechanical systems (economy)

Before any approach to design concepts is attempted, it is necessary to investigate the individual spaces and their convertibility or adaptability to the function of protection and emergency requirements. Some of the factors affecting the convertibility are:

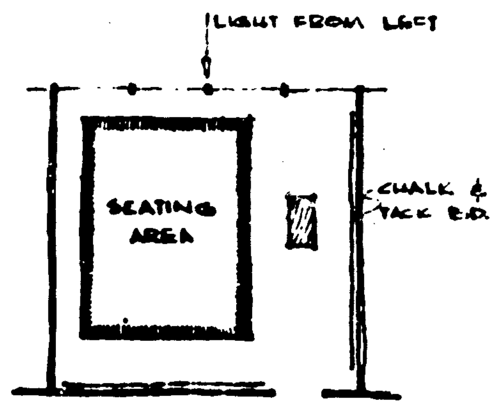
(1) Interior spaces — area, function, and relationship
(2) The degree of flexibility for shelter use
(3) Fixed and movable equipment
(4) General shelter requirements

One of the most important factors related to integrated convertible shelter is the area, organization, and relation of interior spaces. There are many rooms in this type of building that would function better being interior spaces rather than planned with windows along an outside wall, for instance, the assembly room, classrooms for special instruction, conference rooms, mechanical rooms, toilets and storage. In addition to giving full control of illumination and temperature, an interior space will give more flexibility in the interior arrangement for normal functions and an environment better suited for concentration. The degree of convertibility in the various interior spaces depends upon the conventional use, the amount of heavy and fixed furniture and mechanical equipment.

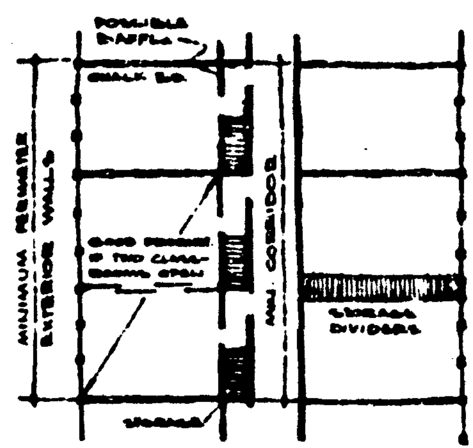
SPACE ANALYSIS

Classrooms

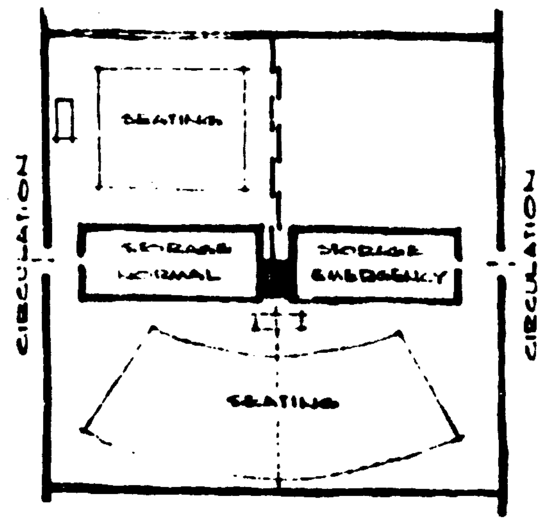
The various types of classrooms are the essential elements



RATIO 1:1
SUGGESTED PROPORTIONS OF REGULAR CLASSROOMS - 20 to 30 STUDENTS



in a school building. The location of classrooms, sizes, proportions, and equipment depends upon variables such as the curriculum and the size and type of classes. There are controversial ideas as to the desirable proportions of a classroom, however, the simplicity of a rectangle can hardly be denied. Many educators and architects believe that the square classroom proportion for general instruction is the best solution and also the easiest adaptable to trainee grouping. Obviously the concept of classroom proportions is going to affect the perimeter of the building and the length of corridors. Since one is concerned with the planning of convertible shelter, one must attempt to conform to the basic principles of protection and economy of shelter. The number of exterior walls, the apertures in these walls, the distance from exterior walls to the interior spaces — all will influence the cost and effectiveness of the convertible shelter solution. Thus, rectangular rooms with a short window wall or a square proportion of the classroom may be better suited for the shelter concept. Both these proportions will offer reduced perimeter and shorter corridors in the building and give flexibility of trainee grouping as well as retaining good proportions when two or more rooms are opened into one larger space.



EXAMPLE OF ARRANGEMENT OF 4 INTERIOR (SPECIAL CLASSROOMS) WITH STORAGE AND FLEXIBILITY

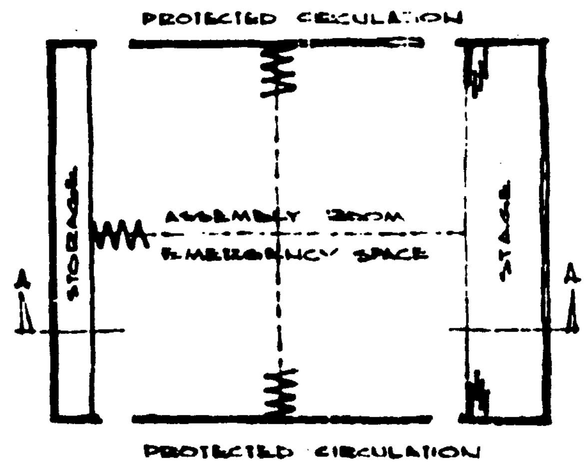
The ceiling height of a classroom varies with the size and proportion of the rooms, the type of lighting, and the function of the room. In a 30 by 30 foot classroom, a clear ceiling height of approximately 11 feet seems to be generally accepted. The height of the room in the shelter area will affect the stacking of bunks and thus the amount of shelterees.

As mentioned above, there are certain classrooms (depend-

ing upon the curriculum and the general policy,) that will provide an improved environment for instruction by being interior spaces. Since most instruction will take place during the daylight hours and TV and other visual aids are gaining acceptance as training aids, it seems desirable to design for a fully controlled artificial environment in these rooms. A certain amount of storage space is generally required in special classrooms, particularly in classrooms where a large number of demonstration will take place. In the interior classrooms these storage areas could be enlarged in order to cope with the emergency requirements. Furniture in classrooms generally consist of movable chairs (sometimes tables and chairs). A large amount of this equipment can quickly be removed and the rest be used for shelter occupancy. One can thus conclude that the interior classrooms if well integrated in relation to other interior spaces, toilets, etc., can give very effective shelter convertibility. These special classrooms could be planned as basement rooms if a basement solution is desirable.

<u>Assembly Room</u>

An assembly room with a seating capacity of 250 is optional in the conventional plan. The main difference between this room and any classroom is that it has a considerably larger capacity. Ceiling height would have to be increased due to the larger area. Furniture (seating) preferably should be of a movable type so that room can be used for various functions. If considered in the planning, the assembly room could be a permanent requirement if it could easily be transformed to serve other functions such as a series of classrooms. This could be solved by the use of a simple arrangement of folding partitions, sliding doors or accordion doors. The required platform stage can



FLOOR PLAN

SECTION A-A

SUGGESTED SOLUTION TO
FLEXIBLE ASSEMBLY ROOM

give a satisfactory answer to the storage problem of chairs. This concept of flexibility may well be adapted to other sections of the school in order to allow maximum variation of classroom sizes and arrangements. The assembly room will, if planned with convertible shelter in mind, give a very efficient space for convertible shelter since it can be an interior space. The larger ceiling height allows for stacking of more bunks per floor area and the space under the raised platform stage can possibly serve as a storage area for emergency equipment. The assembly room should be planned with a direct, or at least protected, access to toilet facilities as well as other shelter areas.

Instructor's Lounge

The instructor's lounge can be close to the staff toilet and should have a central location. Since it can be interior space, the relation to other areas that can be considered for convertible shelter is of importance. The lounge could be equipped with a sink or a counter with hot plate, and could thus possibly double as a food preparation area under emergency conditions.

Crew's Lounge

The crew's lounge can be planned as interior space. A central location, adjacent to trainee toilet facilities should be considered. There should be no reason why the crew's lounge with toilet facilities cannot be planned in connection with the other interior shelter spaces which, in order to give the maximum protection, should be planned either in a basement area or on the middle floor in a multistory building.

Toilet Facilities

In the conventional plan there are general toilets on each floor. In addition, there are toilets for staff and women. The distribution of these toilet facilities depends upon the planning, for example, in a multistory building toilets could be provided on each floor. This may, however, not be the best solution from a convertible shelter point of view, since each one of these toilet units possibly would be inadequate for emergency functions. In this light, a possible answer to both normal and emergency functions would be to concentrate all or most toilets in the protected area. The necessary decontamination facilities could then also be incorporated in this general "wet" area. All toilets will function well as interior spaces.

Storage

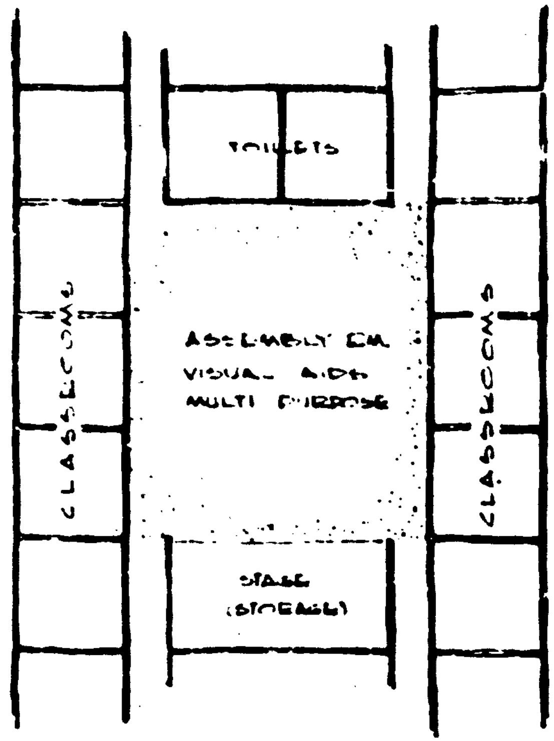
Storage is an important factor both for normal and emergency functions. Thus, the general planning and the type of instruction will dictate the general location. However, regardless of location, there must be additional storage for emergency equipment in the convertible shelter space.

Administration Offices

Administration offices preferably should have exterior light and view. The only exception to this would be the conference room which will only be used for short periods of time. If planned as an interior room, the conference room may be an important additional space to the general shelter area.

Mechanical Equipment Rooms

Mechanical equipment rooms should be interior rooms with



COMBINED CORRIDOR AND
ASSEMBLY SPACE

the necessary intakes, exhausts, and service entrance to the outside. The protection factor in this area does not have to be as high as in the shelter area, but it should be possible to attempt repair of equipment without extreme hazard to the men. The general planning of the mechanical room should be based on minimum distribution lines and maximum efficiency.

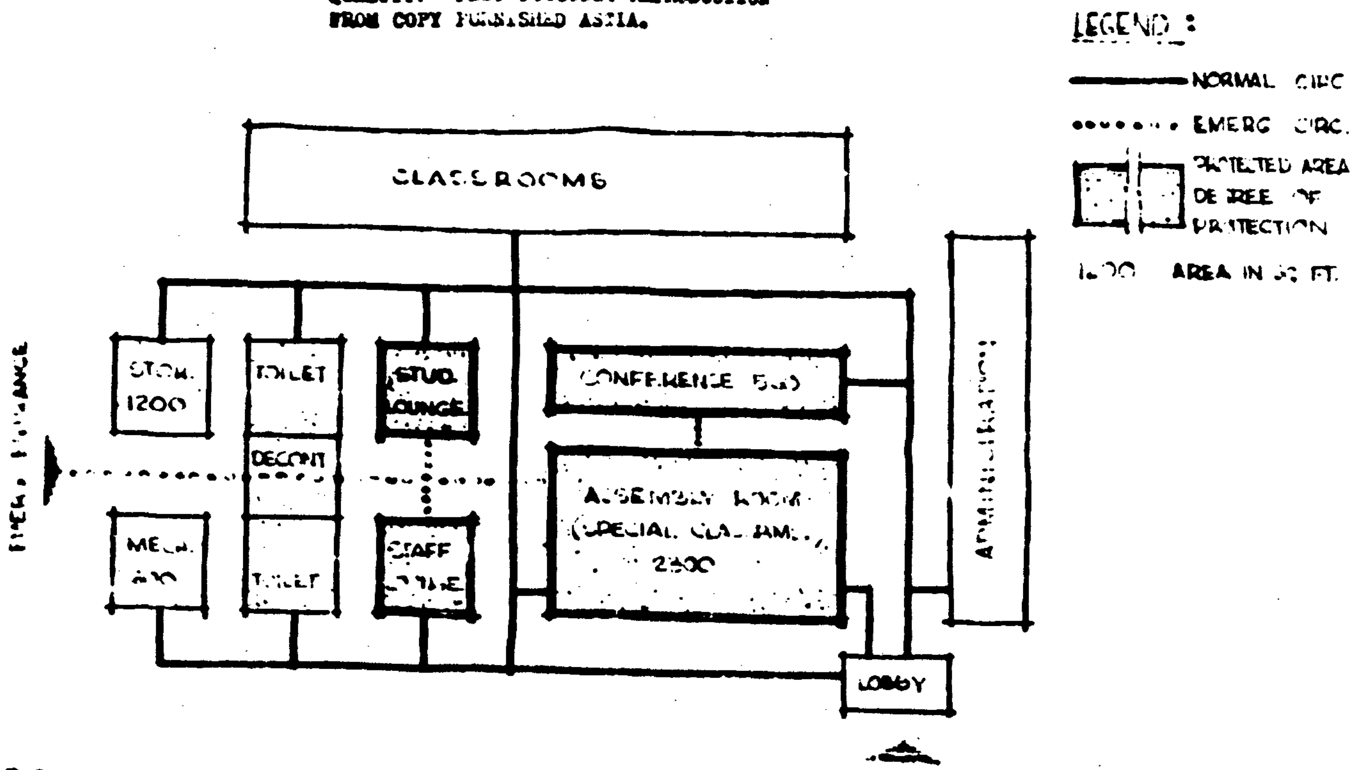
Corridors

The circulation space in a school building is often considered a waste of space for instruction since it is only used for walking and has no instructional facilities. As much as one quarter of the total floor area at times is used for circulation. By enlarging the central corridor this this floor area could become a multi-purpose room, a visual aids room or exhibition space, where every square foot is used for training purposes. To be able to achieve this it may, however, be necessary to increase the depth of the classrooms slightly from the square proportion in order to decrease the length of this space. The planned space may be sub-divided into smaller areas by storage units or toilets. This "corridor" space can serve effectively as convertible shelter space, provided efficient protection can be achieved.

The corridors in general have the advantage of giving good protected space for circulation to other shelter areas. Also, the space normally is free from any obstructions or furniture and can be converted in a minimum amount of time.

Summary

The various types of spaces, which are a part of the Basic Training School and various specific requirements for both normal and emergency functions are summarized in schematic form on the next page.

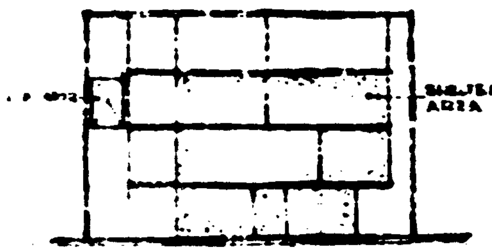


RATIO: [illegible] SPACE WITH NATURAL LIGHT APPROX. [illegible]
INTERIOR SPACE [illegible]
[illegible] 8000
TOTAL AREA [illegible] SQ FT.

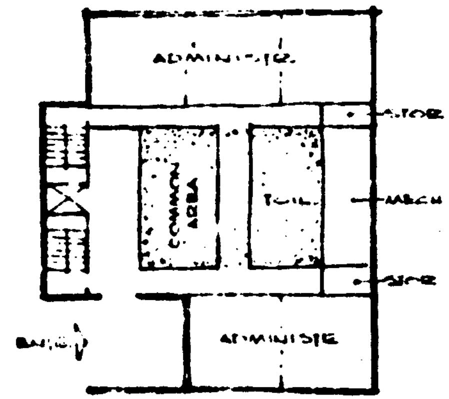
INTEGRATED SHELTER CONCEPTS

CONCEPT 1

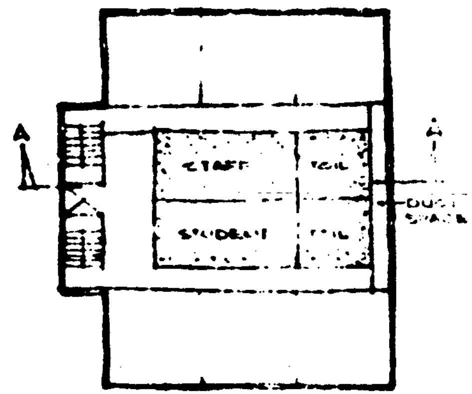
Four story scheme with interior classrooms (not based on inclusion of assembly room, but concept can be adapted to include this). Protected areas at first, second, and third floor. Total floor area approximately 36,000 square feet. Elevator is desirable but not a necessity.



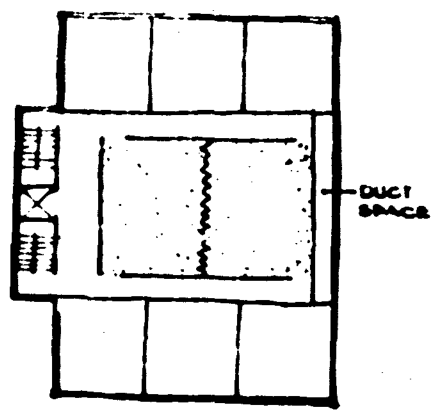
SECTION A-A



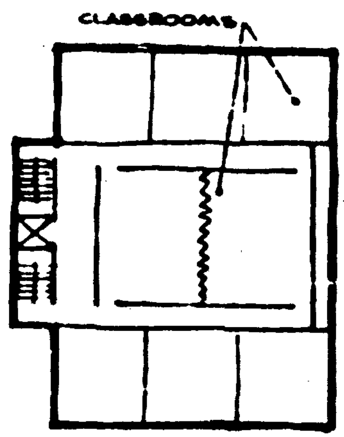
1st FLOOR



2nd FLOOR



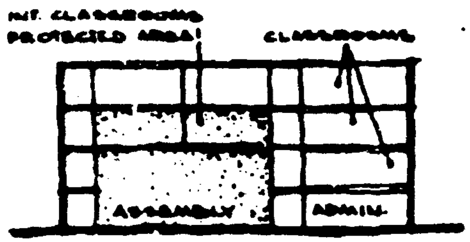
5th FLOOR



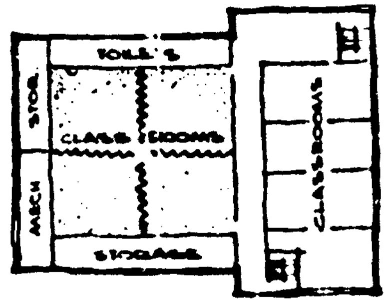
4th FLOOR

CONCEPT 2

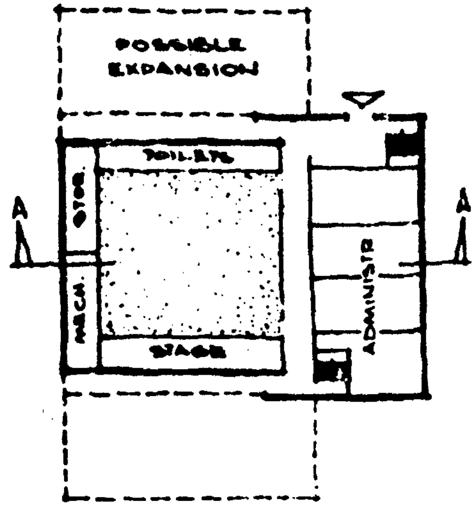
Alternate four story unit with assembly room on first floor and interior classrooms on third floor. Best protection in interior classroom area. Assembly room also can provide protection depending on materials and details.



SECTION A-A



3RD FLOOR



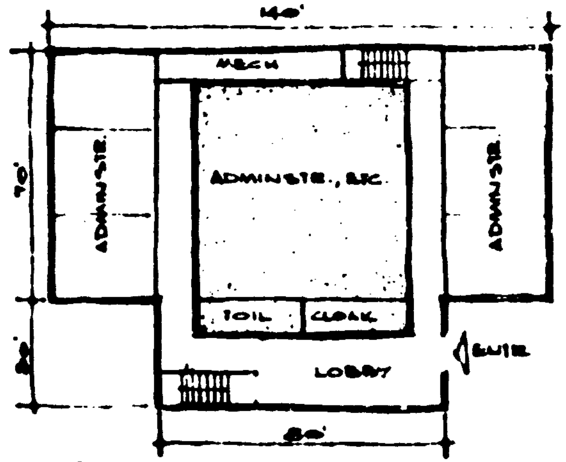
1ST FLOOR

CONCEPT 3

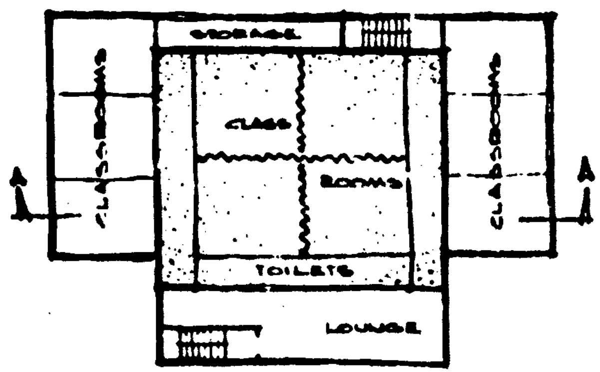
Distribution of spaces to provide maximum effective protection without losing natural light in part of administration and general classrooms. Three-story solution—total floor area approximately 36,000 square feet.

Note

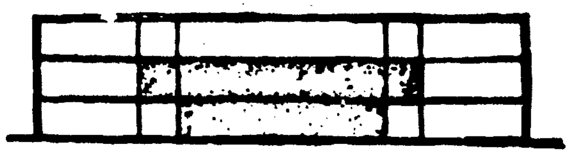
For variations on the planning see building sections, 1, 2, 3, and 4.



1st FLOOR



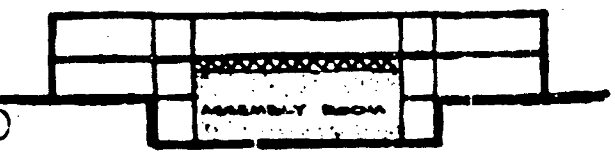
2nd FLOOR WITH SHELTER, 3rd WITHOUT



SECTION A-A

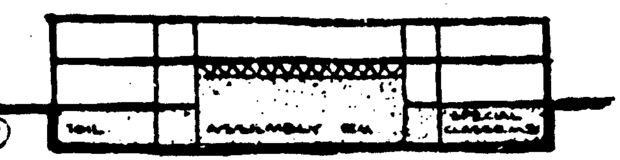
Building Sections

Assembly room in basement
No opening at 1st floor level
Good protection for assembly room



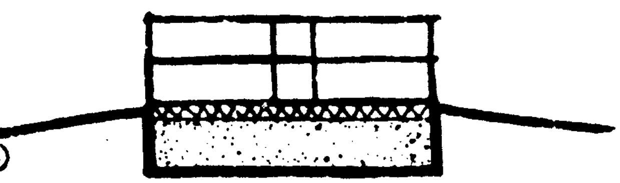
(1)

Assembly room and other interior spaces in basement — core plan. Excellent protection basement spaces. Good protection for assembly room.



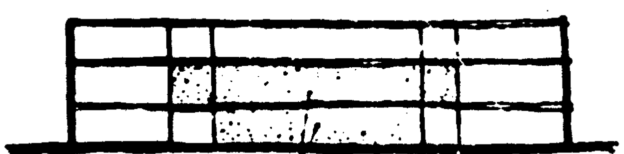
(2)

Assembly room in basement
central corridor system
Excellent protection in basement



(3)

No assembly room, interior in central core three-story building.
Fair protection on first and second floors.



(4) SPECIAL CLASSROOMS & OTHER INT. SPACES

ANALYSIS

CONVENTIONAL REQUIREMENTS

The selected conventional plan of the Administration Building for Naval Air Stations is a simple rectangular two story building 212 feet by 40 feet with a central corridor system. The entrance and lobby are located in the center of the building. The total open area is approximately 17,000 square feet.

Contrary to a larger Administration Building with a more complex function, the selected Building is a rather simplified version, but it will adequately serve as a guide to the basic requirements and functional principles.

In addition to the requirements listed for the selected Administration Building, there may in more complex buildings of the same type, be space allocations for other functions such as:

duplication and drafting	chief clerk office
supply offices with assistant	security offices
snack bar with small kitchen	training offices
public works office	housing
supply and accounts	storage

Basic space requirements for the selected Administration Building:

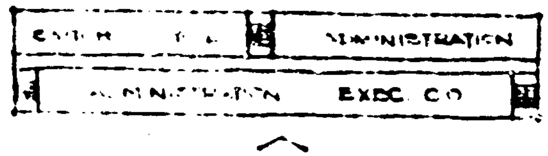
1st Floor

Administration offices	1850 sq. ft.
Marine office	500 sq. ft
Switch room and switch board	720 sq. ft.
Mail room	125 sq. ft.
Commanding Officer, executive officer, and secretary	800 sq. ft.
Comptroller	250 sq. ft.
Two legal offices — total	380 sq. ft.
Chaplain	220 sq. ft.
Officer of the deck	380 sq. ft.
Mechanical	300 sq. ft.
Men's toilet and officer's toilet	380 sq. ft.
Women's toilet	125 sq. ft.
Corridor, lobby, stairs	1850 sq. ft.

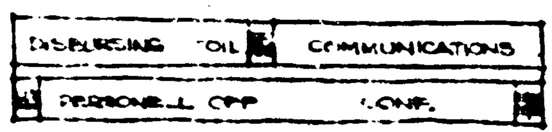
2nd Floor

Communication — including crypto room with vault, teletype, cypher room, communications rooms, communications officer, electronic office and electronic repair all total	1800 sq. ft.
Enlisted personnel, personnel officer, and officer personnel	1800 sq. ft.
Disbursing and disbursing officer	900 sq. ft.
Two offices — total	500 sq. ft.
Conference room	800 sq. ft.
Enlisted men's toilet, women's toilet, and cleaning gear	380 sq. ft.
Corridor, lobby	1500 sq. ft.

The Administration Building is designed without a basement and the materials and construction will vary depending upon the geographical location.



FIRST FLOOR



SECOND FLOOR

ADMINISTRATION BUILDING

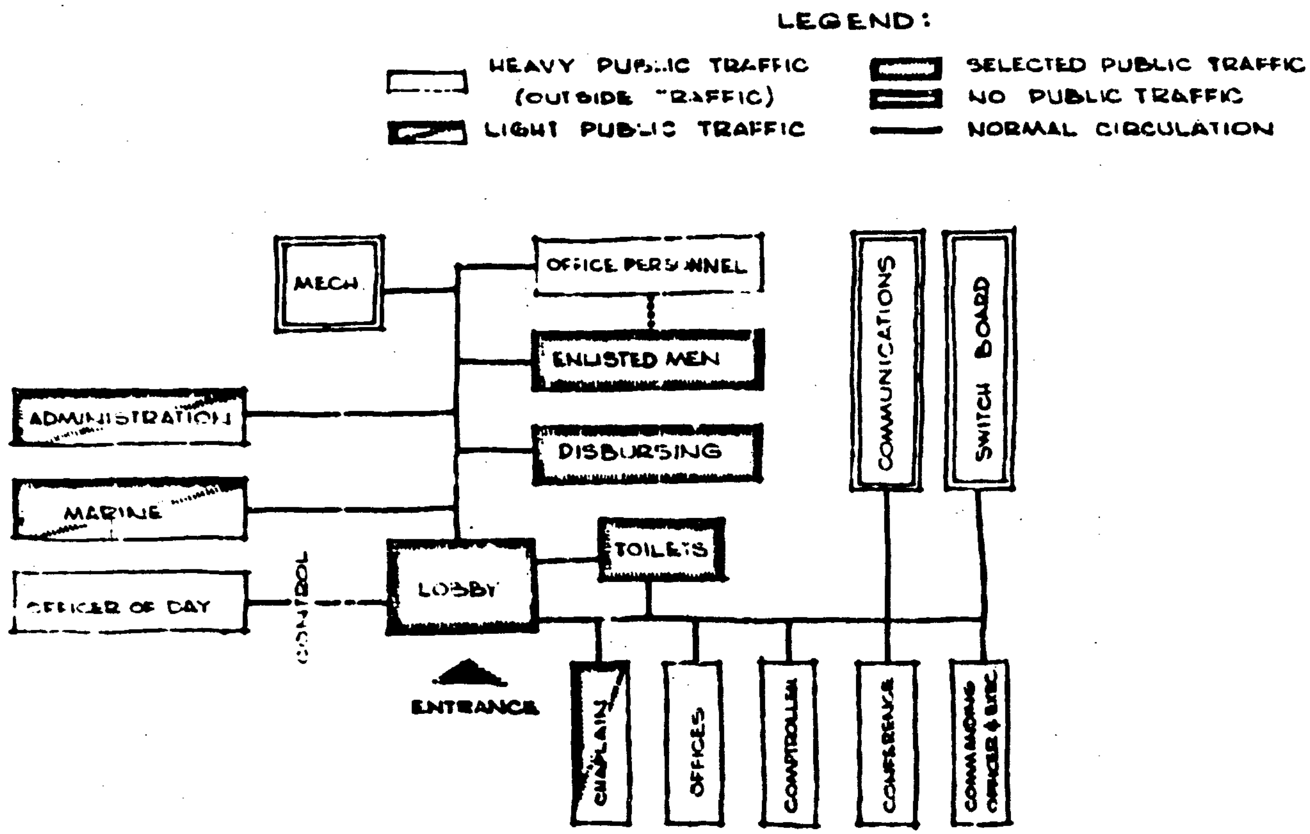
SHELTER CONVERTIBILITY

The conventional two story Administration Building is similar to the Training School in shape and construction, and does not lend itself to shelter convertibility as planned for the same reason as the Training School.

GENERAL PHILOSOPHY

Circulation and efficiency of operation are generally more important planning and design factors in an Administration Building than in buildings with less complicated functions such as Barracks and Training School. In a Naval Station, the Administration Building is the hub of official activity. Under both normal and emergency conditions, orders will originate and be issued from his center, which will also house the commanding officer and this organizational staff. In addition to clerical personnel, the building will be occupied by technical officers and staff necessary for the operation of the Station.

In order to achieve functional efficiency of the building, it is necessary not only to know the functional requirements, but also the method of operation and organization determined by the commanding officer and officers in charge of specialized fields. The organization of the personnel, the administration of the building, and the working environment may well change with the turnover of the commanding officer and his operational staff. In order to cope with these various situations, the planning and design of the Administration Building calls for considerable flexibility. Provided that this is an integrated part of the basic planning,



ADMINISTRATION BUILDING, SCHEMATIC LAYOUT

the flexibility in most cases can be achieved by the use of light, soundproof, movable partitions. The flexibility must not, however, jeopardize the protection in convertible shelter spaces.

In planning for convertible shelter in the Administration Building, it is essential to determine the degree of protection and whether the building will serve as an operational base during attack (and to what degree) or whether it will merely shelter the personnel from fallout and low level blast. The concept of convertible shelter may not meet the requirements for protection if the building is to be used as an operational base during attack. For such functions it would be necessary to design a special purpose building having a high level of protection, hence it cannot be considered a convertible shelter.

Circulation is an important factor for an efficient function of the Administration Building, consequently the building must be designed for:

(1) Internal circulation (the functional relationship of rooms within the building). It should be emphasized, that the vertical circulation generally is less space consuming than a spread out corridor system.

(2) External circulation (the relationship or traffic of persons not working in the building to specific offices within the building) Space needing little outside contact should thus be remotely planned from the lobby. The external relationship of the Administration Building to other buildings at the Base is extremely important not only from a normal day-to-day function but also from an emergency standpoint.

The effect of these factors upon the convertible shelter planning is another consideration. It seems apparent that many of the rooms or spaces with little or no internal or external activity also are the spaces that can be designed for an artificial environment. Whether these rooms should be planned in a basement, along an outside wall without windows, on a second floor, or as rooms in an interior core, depends upon the general design of the building, and how this design relates to the general principles shelter planning.

It should be pointed out that unless an Administration Building is designed with a functional basement, the building should be planned as a three or more story building in order to obtain the best protection at a minimum expense. The "compact" multistory plan will generally give good flexibility to internal function and circulation as well as adaptability to various site conditions. The advantages of a compact plan concept cannot be overlooked:

(1) Shelter convertibility
(2) Minimum perimeter of exterior walls (economy)
(3) Centralization of mechanical systems (economy)

Before any approach to concept colutions is attempted it is necessary to investigate the individual spaces and their convertibility or adaptability to the function of protection and emergency requirements. Some of these factors affecting the convertibility are:

(1) Interior spaces — area, function, and relationship
(2) The degree of flexibility for shelter use
(3) Fixed and movable equipment
(4) General shelter requirements

One of the most important factors related to integrated

convertible shelter is the area, organization, and relation of interior spaces. Many areas in an Administration Building will function effectively as interior space. Past experience has suggested that there are no serious complaints among military personnel to work in an environment where daylight is omitted.

Many executives are of the opinion that a space without outside noise will have less distractions and better working conditions. There should, however, be no reason to design all offices as interior spaces unless a high protection factor is needed; that is, if the Administration Building would serve as an operational command center. Even under these circumstances it could be possible to permit light and view in specific areas that would not be considered operational. In any case, there are certain areas where the nature of the work and the specific equipment may call for an interior environment — the communication unit, conference room, mechanical, switch and switch board room, toilets, and possibly the disbursing unit.

All interior spaces will permit good control of illumination, ventilation, and sound and will also add flexibility to the internal arrangement of the space. The degree of convertibility in the interior spaces depends upon the conventional use, the amount of heavy and fixed furniture, and equipment.

SPACE ANALYSIS

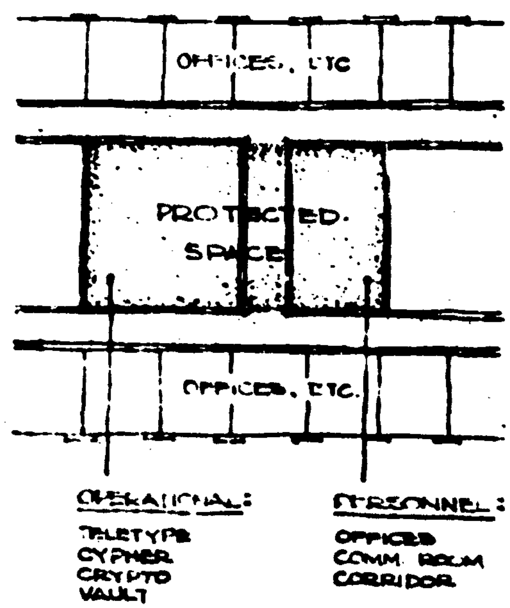
Since in the Administration Building there is a great variety of functional spaces that may not be suited for convertible shelters, only interior spaces that directly or indirectly effect the planning of convertible shelter will be discussed.

Communication Unit

The Communication unit consists of a series of interconnected spaces. A large part of this unit is in the present conventional plan designed without windows. In integrated convertible shelter planning, this complete unit can be considered an interior space. Obviously this particular unit is an essential link in the emergency operation and contains important equipment so it cannot be considered a general shelter area for a large number of men. However, included in the communications unit there are relatively large standard office spaces that could convert to shelter spaces without disturbing the function of the unit as a whole. The subdivisions of the total space must be designed with this in mind in order to lose neither normal efficiency or shelter capacity and/or emergency operation.

Switch and Switchboard Room

This is another operational element that possibly can serve not only emergency functions but provide some shelter space for personnel. To give adequate protection it thus becomes necessary to plan this complete unit as an interior space and preferably in the same area as the communications facilities and other interior shelter areas. A considerable amount of fixed operational equipment will reduce the potential use for personnel protection. Corridors or other spaces may have to be used for this purpose. Specific areas require good acoustical properties.



COMMUNICATION UNIT

Conference Room

Due to the function and short time occupancy of the conference room, it can be planned as interior space. Light, easily movable furniture will add to the convertibility of this space. The conference room thus becomes one of the most effective shelter spaces in the Administration Building. However, there obviously are space limitations regarding the capacity of sheltered personnel. To provide effective shelter for a large number of operational personnel, one may also have to plan other units or rooms as interior spaces.

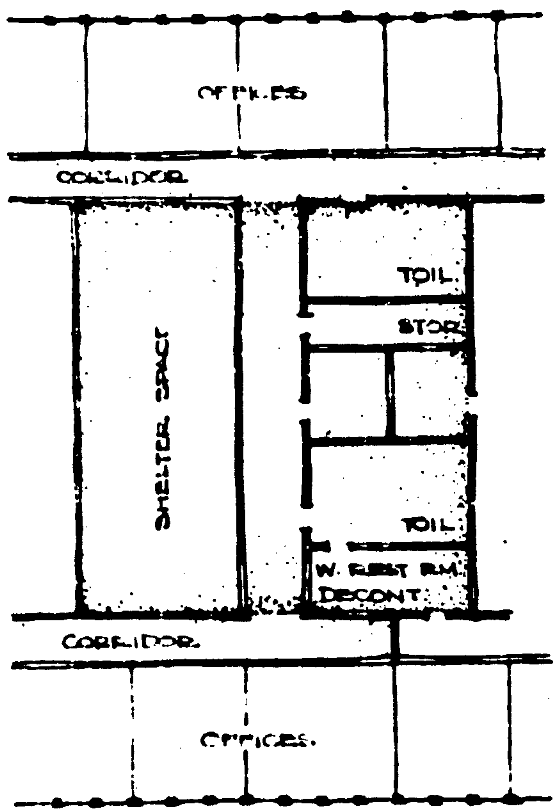
Disbursing Offices

These may be planned as interior spaces, hence will add considerably to the general shelter area. If the space is well planned with convertibility as a basic criteria, the equipment and furniture in these offices should cause no serious problem.

Toilet Facilities

Toilets should be divided in several units to effectively serve the normal functions. Thus in the conventional plan there are: one women's toilet, one officer's toilet and two enlisted men's toilets.

Regardless of the planning of the building these minimum toilet requirements should be kept. To provide effective emergency toilet facilities, most of the toilet rooms should be designed in such a way so as they can be reached through protected areas. The total number of toilets and lavatories



CONCENTRATION OF TOILETS FOR GREATER ECONOMY AND EMERGENCY CONVERTIBILITY. DECONTAM. INCLUDED.

for shelter use depends upon the total shelter capacity and system. It thus may be necessary not only to combine all the required conventional toilet facilities but also to have chemical toilets to cope with the emergency situation. The conventional plan shows toilet facilities for certain offices. If possible, these toilets should be centralized to minimize plumbing expense. Decontamination facilities should preferably be included in the shelter toilet areas.

Mechanical Equipment rooms will require the same considerations as mentioned in the discussion above, regarding the Training School.

Circulation space should also be protected to provide additiona shelter space.

The interior spaces briefly discussed above thus will have to be planned as some sort of a core with a concentration of all emergency operational activities as well as protection for the necessary personnel. Additional shelter space may have to be considered in the basic planning if a larger number of personnel is to be protected. The Administration Building, due to its specific functions, is thus better suited for a convertible shelter for its operating personnel rather than a shelter for a larger mass of transient men.

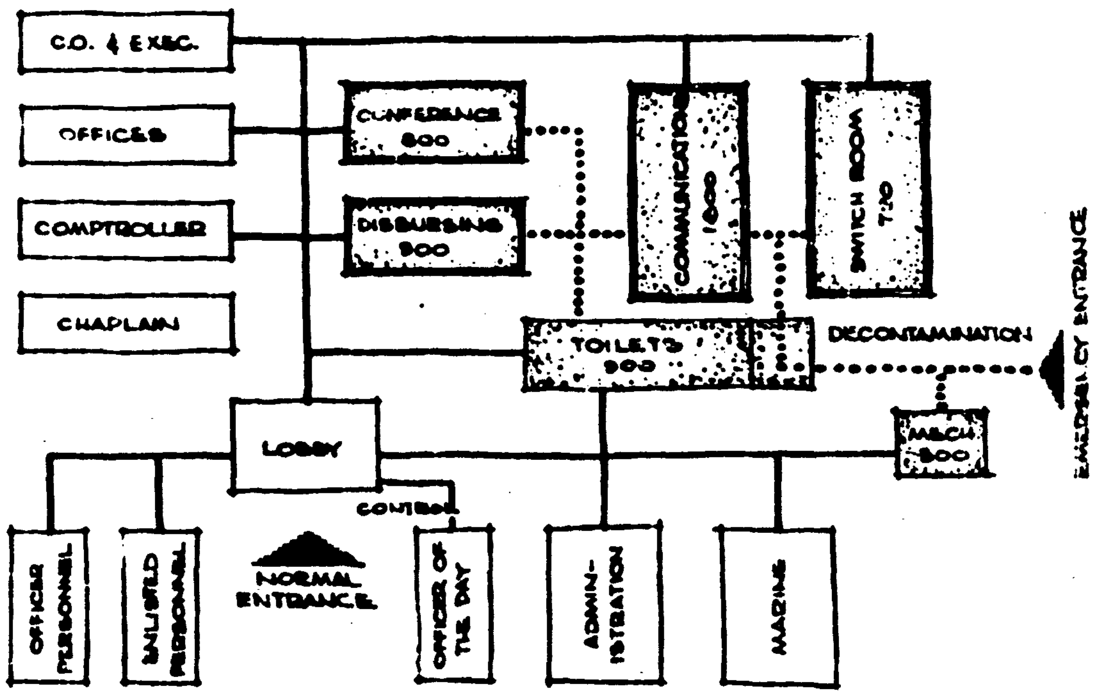
Summary

The various types of spaces, which are a part of the Administration Building and various specific requirements for the design for both normal and emergency functions are summarized in schematic form illustrated on the following page.

SPACE WITH NATURAL LIGHT	APPROX.	7500 SQ.FT.
INTERIOR SPACE		6000 SQ.FT.
CIRCULATION		3500 SQ.FT.
	TOTAL AREA	17,000 SQ.FT.

LEGEND

- NORMAL CIRCULATION
- EMERG. CIRCULATION
- PROTECTED AREAS DEGREE OF PROTECTION
- 800 AREA IN SQ.FT.



INTEGRATED SHELTER CONCEPTS

CONCEPT I

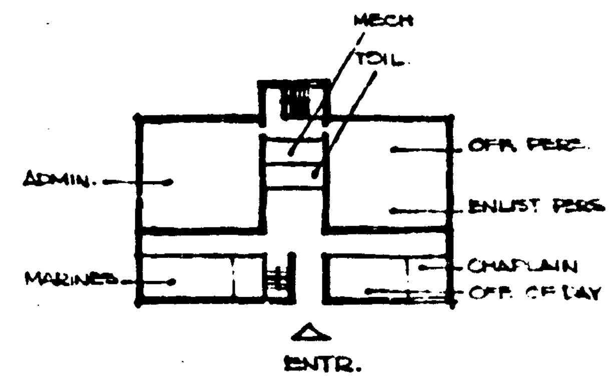
Distribution of spaces according to circulation. Three floors — operational elements in protected area. Windows in first and third floor only. No apertures in second floor exterior walls. Regardless of materials used, protection relatively low and expensive. Operational elements in a basement, possible solution — high protection. Total floor area approximately 17,000 square feet.

Advantages

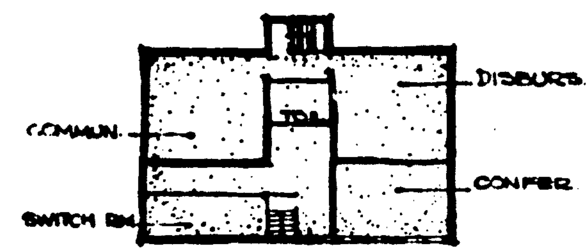
Short perimeter of building. Central toilets. Little wast of space.

Disadvantages

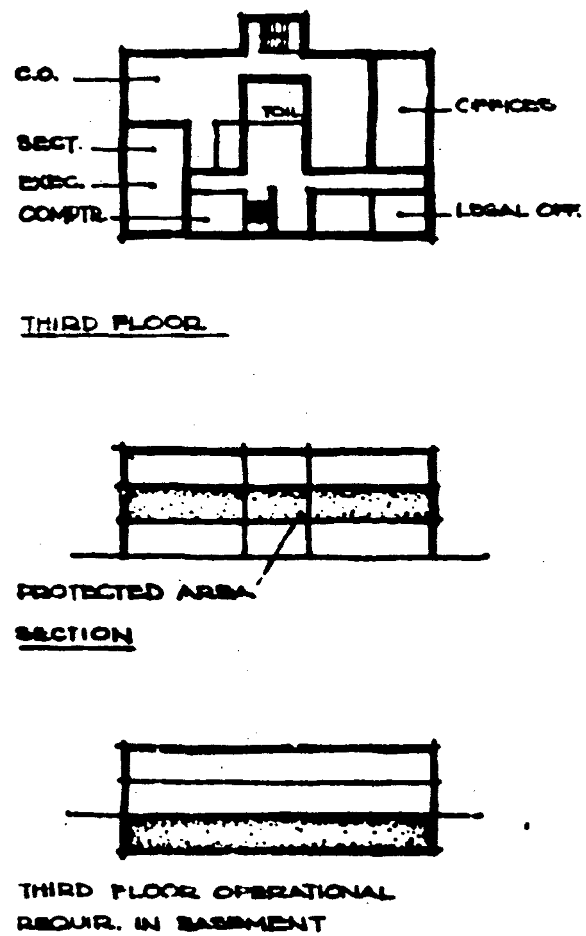
Protection on second floor only (for operational personnel) Excessive mass thickness needed in exterior walls of second floor (protected area).



FIRST FLOOR



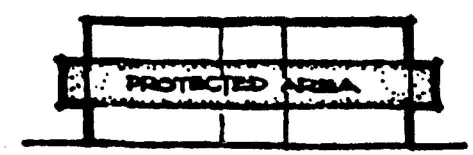
SECOND FLOOR



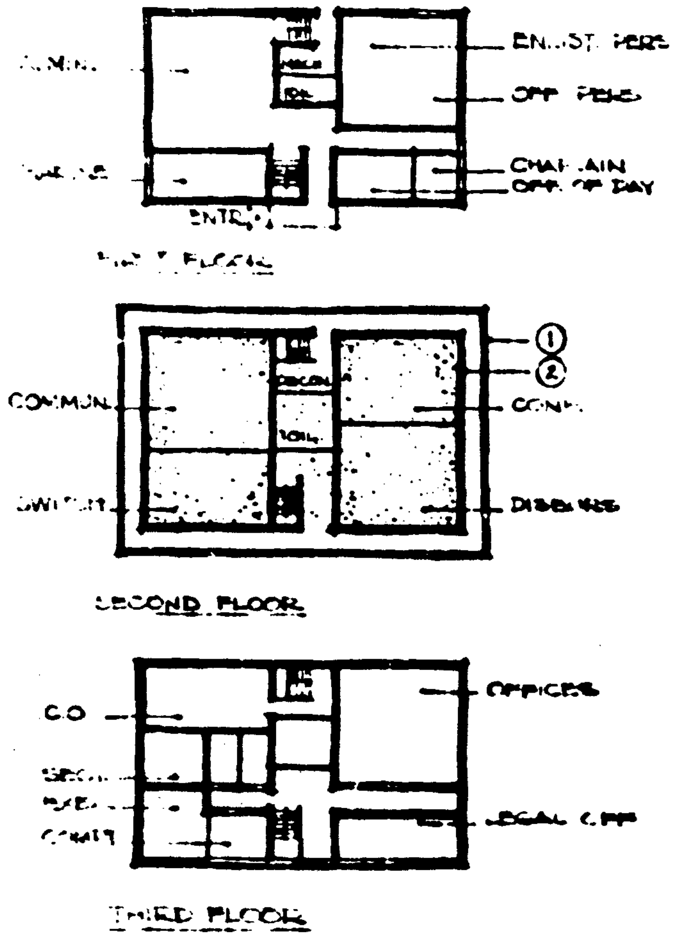
CONCEPT 1

CONCEPT 2

General solution as Concept 1 except change to perimeter circulation system on second floor. Mass thickness in wall 1 and 2 in sketch will provide better protection in interior shelter areas. If floor, ceiling, and walls in corridor on the second floor are provided with adequate shielding materials, circulation space could be used for additional shelter. Otherwise corridors should only be used for circulation untill radiation is low enough to permit use of this space.



SECTION



CONCEPT 2

CONCEPT 3

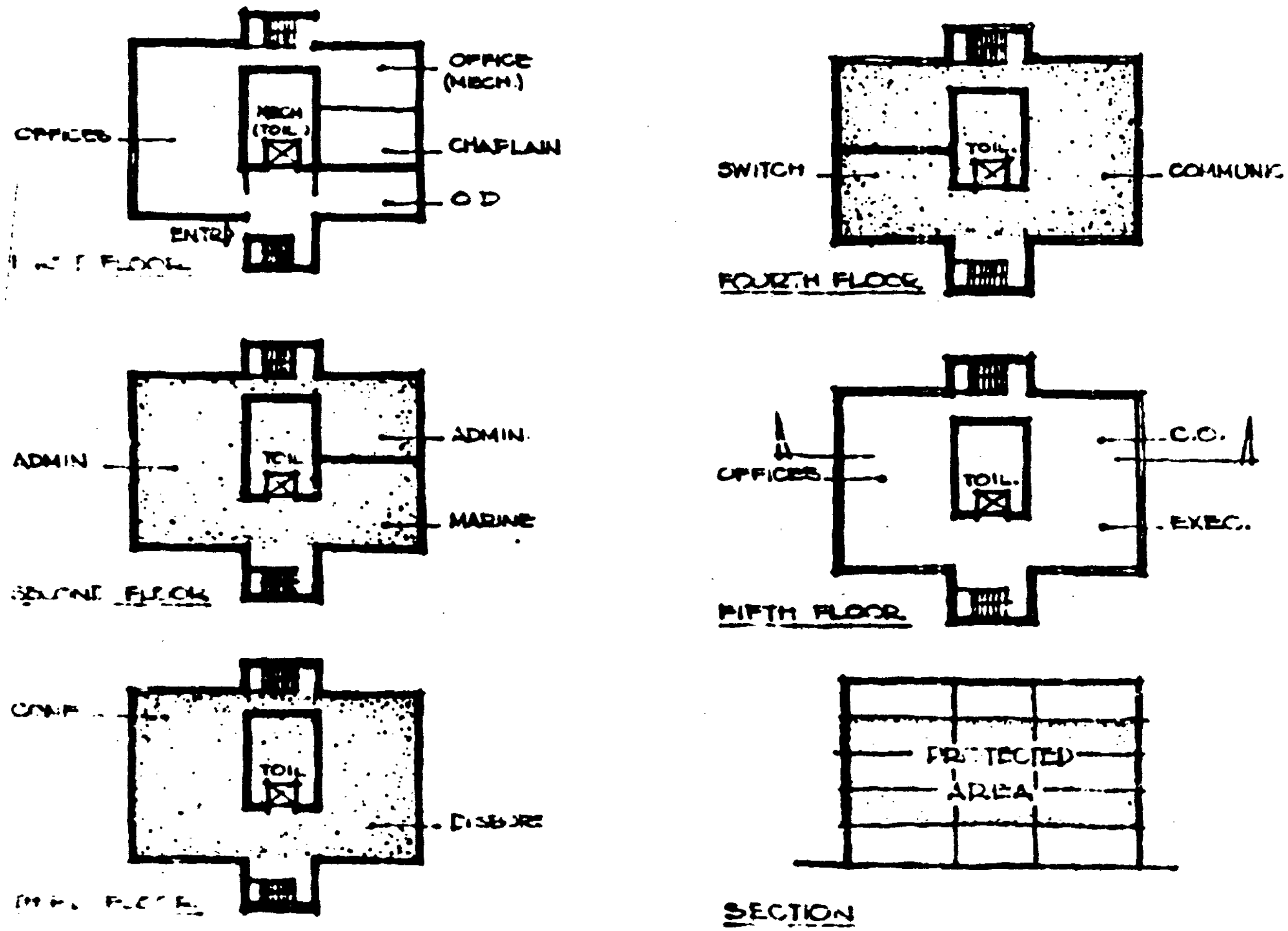
Five story building (with elevator). No windows on second, third, and fourth floor. Total floor area approximately 17,000 square feet.

Advantages

Increased protected area both for operation offices and personnel. Second, third, and fourth floors can be used with best protection on third. Central mechanical services and plumbing. Effective utilization of space.

Disadvantages

Due to single exterior wall in protected area, excessive and expensive mass thickness is needed.



OFFICES
OFFICE (MECH.)
MECH (TOIL.)
CHAPLAIN
O D
ENTRY
ADMIN
TOIL.
ADMIN.
MARINE
SECOND FLOOR
TOIL
SWITCH
TOIL.
COMMUNIC.
FOURTH FLOOR
OFFICES
TOIL.
C.O.
EXEC.
FIFTH FLOOR
AREA
SECTION

CHAPTER SEVEN — 100 BED HOSPITAL

ANALYSIS

INTEGRATED SHELTER CONCEPTS

ANALYSIS

CONVENTIONAL REQUIREMENTS

The existing conventional plan is a two-story, modified H-shaped building, containing all requirements for a standard general 100 bed hospital. It would be going beyond the scope of this guidebook to analyze and study the individual room arrangement and requirements; only the major units and departments will be discussed as they relate to convertible shelter planning.

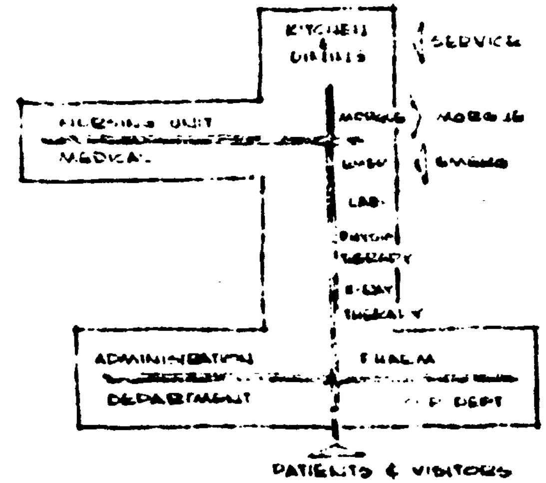
In the following tabulation of the requirements, the approximate area will be listed for all major elements only.

Administration Department, (approximately 4000 square feet) includes in addition to the normal requirements, offices for commanding officers and executive and Red Cross officers.

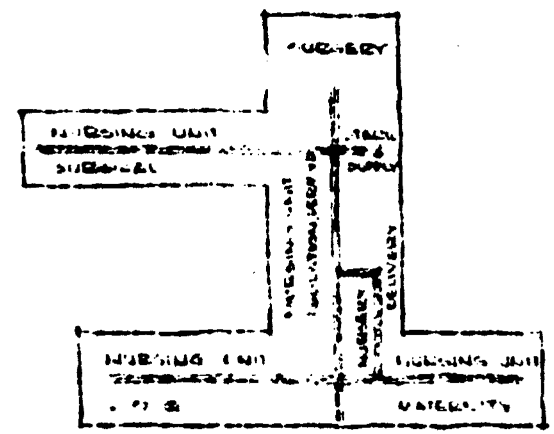
Outpatient Department (approximately 4000 square feet.) In connection with the outpatient department, there are a number of treatment rooms (adjunct facilities) that will be used both by outpatients and non-ward inpatients.

Adjunct Facilities
Each subgroup will have the specific floor area listed.

(a)	Dental surgery	400 sq. ft.
(b)	Ear, nose and throat	1200 sq. ft.
(c)	Electrocardiography and basal metabolism	500 sq. ft.



FIRST FLOOR



SECOND FLOOR

THE ORIGINAL ... WAS OF POOR
QUALITY. ...
FROM COPY ...

(d) X-ray and radiation	1600 sq. ft.
(e) Physiotherapy	600 sq. ft.
(f) Laboratory	600 sq. ft.
Total	8900 sq. ft.

Emergency Department including emergency operation, examination, and bedroom approximately 1200 to 1500 square feet.

Morgue 300 to 400 square feet

General Storage, and baggage room, approximately 600 square feet.

Kitchen and Dining — dining area for 64 persons in one sitting — kitchen facilities for total hospital 4200 to 4500 square feet.

Nursing unit, 32 medical beds — includes ward for 28 enlisted men, 2-two bedrooms with bath, toilet, and general functional facilities approximately 6000 square feet.

Surgery Department consisting of 3 major operating rooms, cystoscopy, recovery room, central sterilizing and supply, chief surgeon's office and other conventional requirements 5500 to 6000 square feet.

Nursing Unit, 32 surgical beds (ward and rooms same as medical beds) approximately 6000 square feet.

Nursing Unit for V.D. and Dermatology and Isolation
Total of 10 beds - 2000 square feet

Distribution of beds:

4 bed ward for V.D.
4 bed ward for Dermatology
2 Isolation rooms

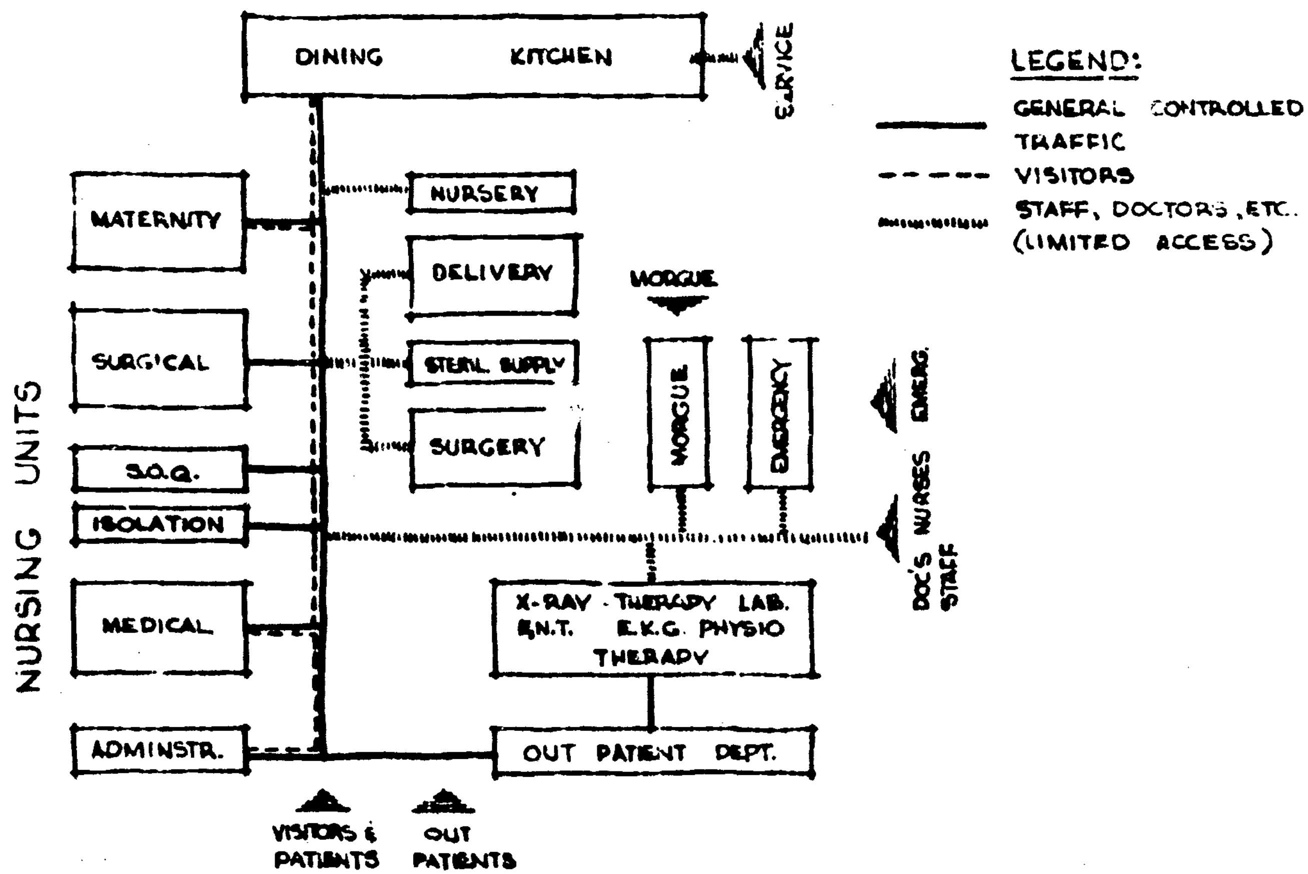
Nursing Unit S.O.Q., total of 16 beds, includes:
7 two bedroom units with toilet and showers in pairs and 2 isolation rooms — 4000 square feet.

Maternity Department total of 13 beds includes:

(a) Delivery	1600 sq. ft.
(b) Nursery	1200 sq. ft.
(c) Nursing Unit	4000 sq. ft.

Miscellaneous space requirements include chaplain's office, welfare office, maintenance office, mail room, shops, supplies, and mechanical rooms. Most of these functions can be located in the basement if such exist.

The conventional 100 bed hospital is usually designed with a partial basement. Materials and construction may vary depending upon the geographical location.


DINING
KITCHEN
SERVICE
NURSING UNITS
MATERNITY
SURGICAL
S.O.Q.
ISOLATION
MEDICAL
ADMINSTR.
NURSERY
DELIVERY
STERIL. SUPPLY
SURGERY
MORGUE
MORGUE
EMERGENCY
EMERG.
DOC'S NURSES STAFF
X-RAY - THERAPY LAB.
E.N.T. E.K.G. PHYSIO
THERAPY
OUT PATIENT DEPT.
VISITORS & PATIENTS
OUT PATIENTS
LEGEND:
GENERAL CONTROLLED TRAFFIC
VISITORS
STAFF, DOCTORS, ETC. (LIMITED ACCESS)

SHELTER CONVERTIBILITY

The conventional two-story hospital is planned with considerable depth in the central section and with a number of interior spaces. With a proper selection of materials, these spaces can give a fair protection especially on the first first floor. The existing basement can provide excellent shelter facilities for personnel if mass thickness in floor above is adequate. The x-ray and radiation department has been shielded from within to the outside environment by the use of mass thickness in walls, floors and ceilings and lead filler in doors. (Shielding for x-ray purposes is not necessarily good protection against gamma radiation.)

The conventional plan in this way permits some protected areas depending on the material selection. However, protection for both staff and patients cannot be achieved with this very limited space. Furthermore, without considerable modifications, the spaces available will not give adequate protection for prolonged emergency occupancy and meet the tolerance levels indicated above.

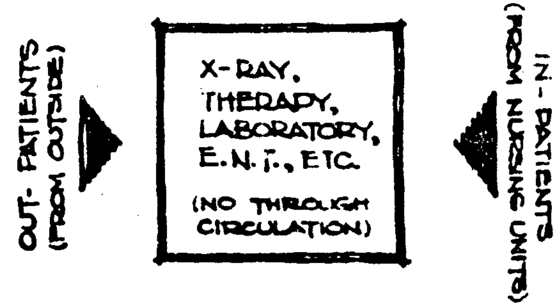
GENERAL PHILOSOPHY

A well studied and developed program is the first step in any hospital design. In this programming, one will arrive at basic requirements regarding capacity of various departments, and the inclusion of special fields. Where convertible shelter is being considered for a hospital, effective protection becomes a major part of these requirements. Before the preliminary planning is started, it is essential to determine the emergency capacity of the hospital, as:

(1) Operational with reduced capacity
(2) Operational with a full capacity
(3) Operational with an emergency capacity such as admitting a large number of casualties for treatment and care, (civilians could be included). The hospital would thus act as a major emergency center and would have to have extended facilities.

Establishing the system and operational criteria for both normal and emergency functions will thus provide the basic data for the convertible shelter planning in the hospital.

Smooth operation of the hospital will demand planned integration of the various functioning elements; for instance the medical and surgical departments operate as individual units, but they depend on services from other departments and units. Other departments and services have a dual function as the X-ray, therapy, laboratory, and ear and nose and throat; and will serve both the inpatient (ambulatory and non-ambulatory) and outpatients. These departments, however, must not act as a major ingress and egress to other departments.



The degree of integration of normal and emergency functions (convertibility) depends upon the emergency capacity; for instance kitchen facilities and food services may have to be so integrated with the shelter space that 100% service is maintained during emergency. The peacetime emergency entrance may, under emergency conditions, serve as a main entrance with decontamination facilities. The particular function for both normal and emergency activities thus plays an important role in the location of specific adjunct facilities.

In order to achieve good integration, the circulation system in the hospital is a very important factor. Major factors in the circulation system include:

(1) Minimum cross-traffic and congestion
(2) Maximum efficiency with a minimum of steps and effort
(3) Hygienic separation

The circulation that governs the planning of a hospital can be termed as outside traffic and inside traffic. Outside traffic may include: arrival and departure of patients, visitors and public parking and entrances, staff parking and entrance, supply and services, emergency entrance, and removal of dead, (shelter entrance may be considered with one or more of these). Inside traffic may include: inpatients and outpatients, doctors and nurses and staff visitors.

In the distribution and organization spaces, a planned flexibility both for the present and the future is desirable for good normal function. These requirements are magnified with the introduction of convertible shelter and must be considered at the preliminary planning stage.

The general layout and organization of the major functional elements tend to dictate the shape of the building. In small hospitals, a one-story pavillion type may give a satisfactory solution for the normal function, but will not give adequate protection for shelter use without excessive and expensive mass thickness. A two-story hospital may add to the protection if the shape of the building and the materials selected are appropriate. A hospital with three or more stories in a compact plan solution will offer the best solutions for convertible shelter without great increase in cost. A multistory hospital will depend upon mechanical vertical transportation, but this additional expense can easily be justified by the:

(1) Decreased perimeter of building
(2) Simplification of structure
(3) Most mechanical services in an interior core or other concentrated area
(4) Shelter convertibility

The dispersion of various departments and facilities are frequently expressed in the shape and basic layout of the building such as: T-shape, H-shape, and L-shapes. There should, however, be no difficulty in obtaining the same amount of dispersion by vertical segregation of these elements in a more compact plan solution.

An emergency function, even at a reduced capacity will require a large protected area to house the various functions, and this area would have to be some sort of an interior space to achieve effective and inexpensive pro-

tection. The degree of flexibility of these spaces will depend upon fixed and movable equipment, general shelter requirements, and location within the building.

In extreme cases, the total building virtually could be enclosed in a protective envelope. However, due to the psychological and therapeutic health values of sun, light, and view and the fact that one is dealing with sick people who are confined to one space for long periods of time, it seems logical to provide, nursing units with natural light and view.

The administration department and outpatient department could also be spaced with exterior view without seriously effecting the emergency function of the hospital. With these exceptions, the total building could be planned as a series of interior spaces which, in addition to giving full control of illumination and ventilation, would simplify the mechanical systems, increase interior flexibility, and shorten and concentrate traffic lines.

A hospital with shelter facilities must be considered basically an operational shelter only regardless of capacity it can only give protection to the ...ry staff and patients and not a large number of ... de personnel. The Barracks and the Training School are better suited for the concentration of a large group of men.

SPACE ANALYSIS

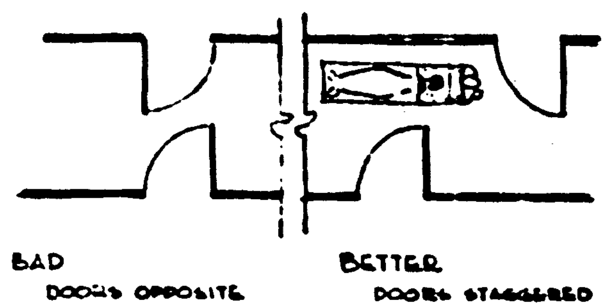
The complete 100 bed hospital consists of a large number of integrated spaces with various functions and requirements and it would be beyond the objective of this guidebook to analyze all these spaces. Only the elements that directly or indirectly effect the convertible shelter planning will be discussed.

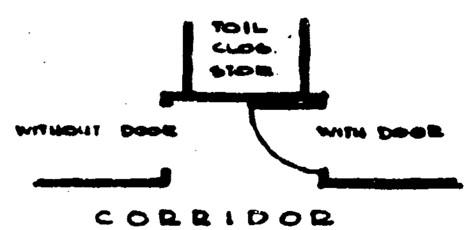
Rooms and Wards

Unless a complete enclosed hospital is planned, the room details will not effect the convertible shelter concept directly. However, the size, proportions, and organization may effect the general building shape, the length of corridors, and the convertible shelter planning in the hospital. If the rooms are adjacent to a corridor that is considered a protected space, the location of fenestration in relation to doors becomes important.

Corridors

In a hospital planned for convertible shelter, the corridors may be the solution to sheltered bed space where wards and rooms are not designed for convertibility. This obviously means that the corridors will have to be interior spaces with adequate mass thickness to meet the established tolerance levels for protection. Doors to spaces with windows and other openings must be baffled and/or door material must have the necessary mass thickness to avoid radioactive penetration. The normal width of corridors should be no less than 8 foot to allow adequate space for rolling equipment. With a special arrangement, it may also be possible to stack the beds two high along the corridor walls. The auxiliary facilities in a nursing unit will be adjacent to corridors and thus one can achieve an emergency operating nursing unit with the corridors serving





as wards for patients. Emergency outlets for oxygen and power could be planned in the corridors.

Kitchen

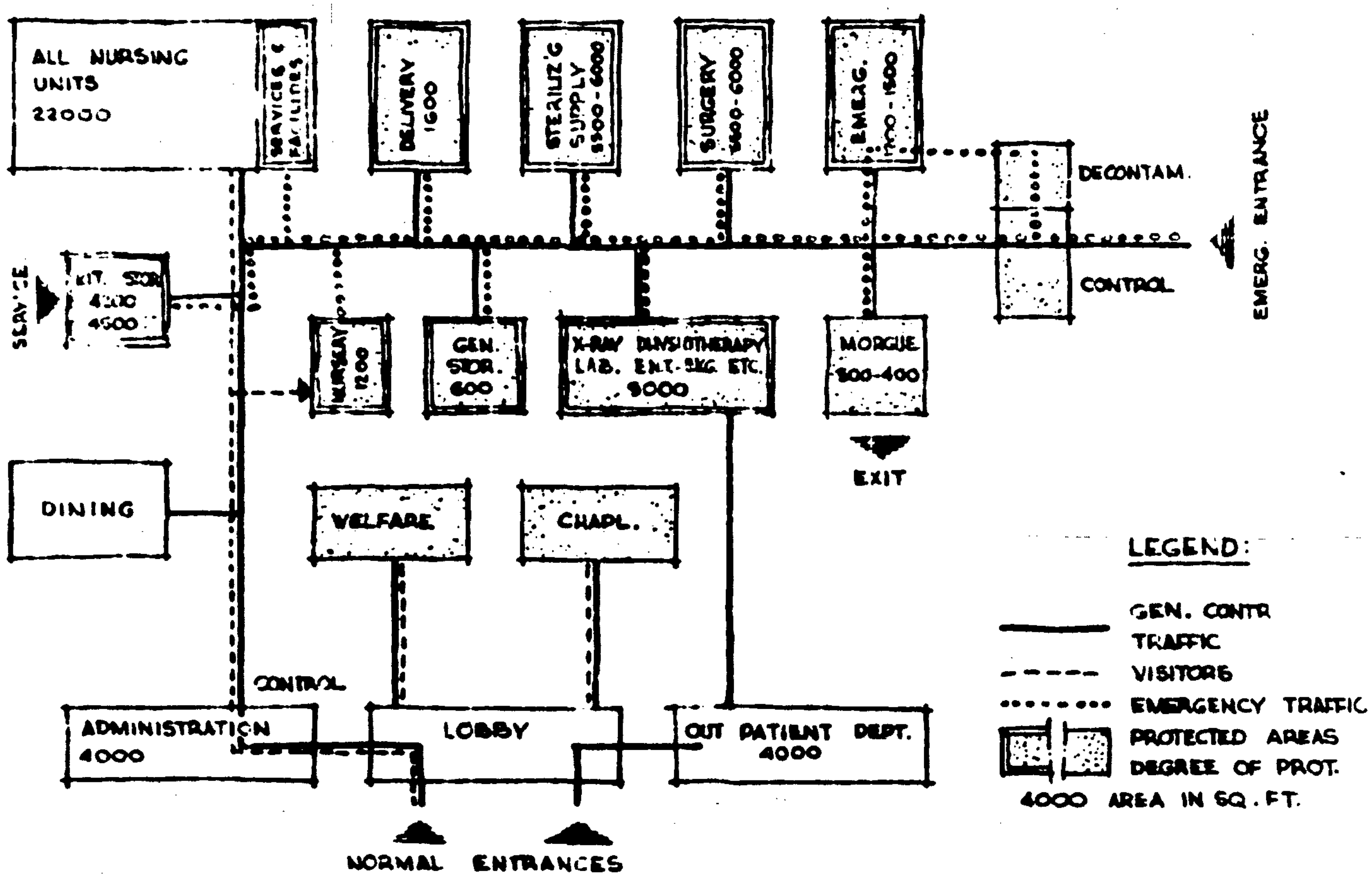
The kitchen and food supply areas must be interior spaces affording shelter protection for personnel. When a full emergency capacity is planned for the hospital, the storage should be oversized to allow 14 days storage. The distribution lines of prepared food to the various units must have a certain amount of protection. In hospitals where reduced capacity is anticipated, the diet kitchen with adequate storage for emergency food packages may suffice.

A storage capacity for at least 14 days emergency operation must be provided in all departments. This means that the normal storage space must be enlarged.

In general, the circulation and control of traffic must be retained during emergency conditions, but certain office spaces and corridors may be used for additional quarters with bunks for doctors, nurses and other personnel.

Summary

The various types of spaces, which are a part of the 100 bed hospital, and various specific requirements for the design for both normal and emergency functions are summarized in schematic form on the following page.



ALL NURSING UNITS 22000
SERVICES & FACILITIES
DELIVERY 1600
STERILIZ'G SUPPLY 5500-6000
SURGERY 5600-6000
EMERG. 1100-1500
DECONTAM.
CONTROL
EMERG. ENTRANCE
SERVICE
KIT. STOR 4000 4600
NURSERY 1200
GEN. STOR. 600
X-RAY PHYSIOTHERAPY LAB. ENT.-SKG ETC. 9000
MORGUE 300-400
EXIT
DINING
WELFARE
CHAPL.
CONTROL
ADMINISTRATION 4000
LOBBY
OUT PATIENT DEPT. 4000
NORMAL ENTRANCES
LEGEND:
GEN. CONTR TRAFFIC
VISITORS
EMERGENCY TRAFFIC
PROTECTED AREAS
DEGREE OF PROT.
4000 AREA IN SQ. FT.

INTEGRATED SHELTER CONCEPTS

CONCEPT 1

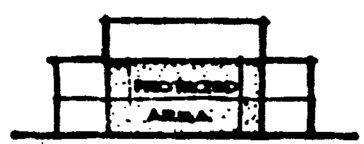
Three story solution with a core concept. Nursing units, administration and outpatient departments can act as a buffer for internal core. Some spaces as kitchen, dining, and emergency that are planned along outside wall will require additional shielding. Third floor over interior core only to minimize roof contribution. These spaces will not be permanently used during emergency.

Advantages

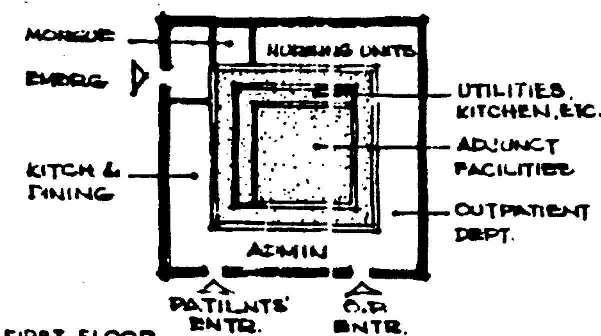
The reduced exterior walls and concentrated mechanical and plumbing facilities tend to lower the initial cost of building. Concept provides good protection in all interior spaces without extreme mass thickness exterior walls.

Disadvantages

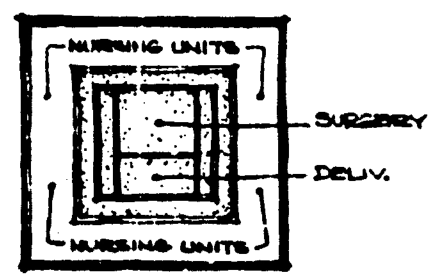
Solution may require area adjustment of the various departments and facilities to compensate for the square building shape. Too much circulation through nursing units.



SECTION



FIRST FLOOR



SECOND FLOOR

THIRD FLOOR

CONCEPT 2

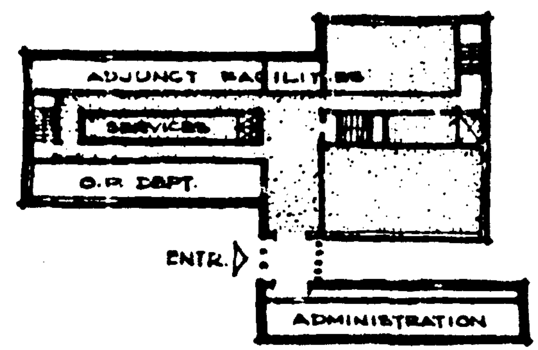
Four floors above ground, with administration department in a separate wing. All nursing units based on smaller wards than conventional plan. Wards and rooms in these units planned along outside walls with windows. Rooms act as a shield to the protected areas. Corridors used for patients emergency quarters. Shelter spaces along exterior walls require additional mass thickness for protection, no windows in these areas. Plan can be solved not exceeding the floor area of the conventional hospital building.

Advantages

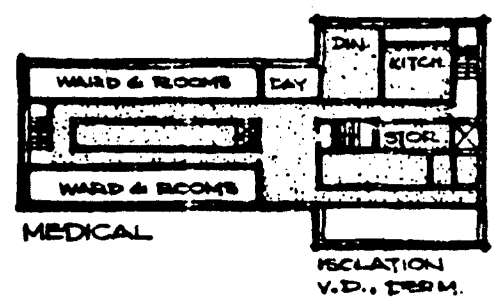
Good protection possible in the internal areas, without complicating hospital function. Fair concentration of mechanical and plumbing facilities is possible.

Disadvantages

Building somewhat complicated in the basic concept, but can possibly be simplified by further study. Large wards are not possible.

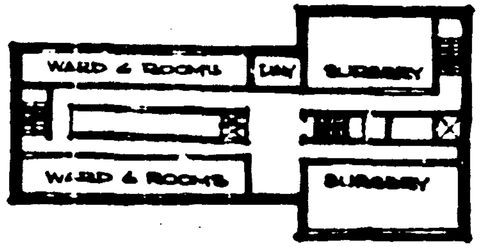


FIRST FLOOR

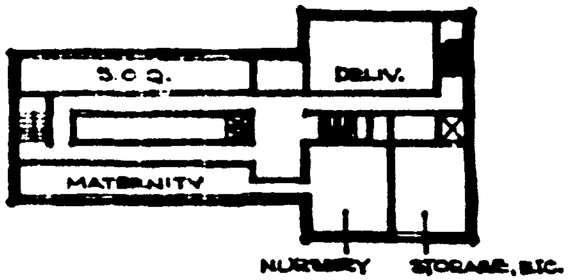


SECOND FLOOR

CONCEPT 2



THIRD FLOOR



FOURTH FLOOR

CONCEPT 2

CONCEPT 3

A combination of a three (unprotected) and a four story (protected) unit. Distribution of spaces and their relative sizes are possible within the conventional building area. The large wards in the nursing units are retained. Corridor used for protected patient quarters. Additional shielding in protected areas can be obtained by the location of storage and similar services along outside walls.

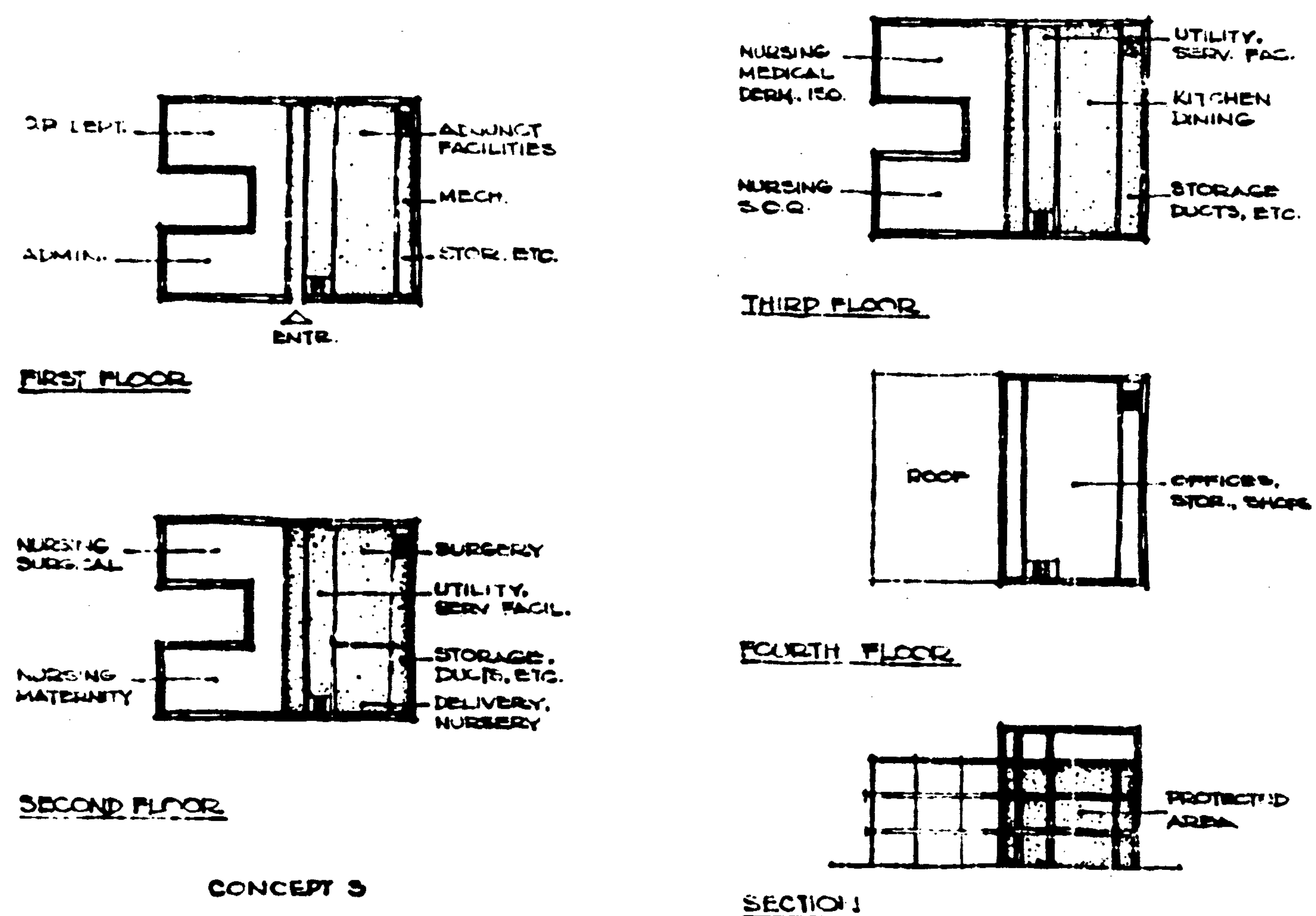
Advantages

Solution offers a clear division between protected and unprotected spaces as well as a sound functional organization of the various departments and services. Good protection is possible in all internal spaces.

Solution is realistic and offers an effective answer to the shelter problem in an emergency operational hospital. Concentration of mechanical and other services minimizes the initial cost.

Disadvantages

Kitchen located on an upper floor requires additional vertical transportation system. The large space available on the upper floor over-sized but necessary for protection.


OP DEPT.
ADMIN.
ADJUNCT FACILITIES
MECH.
STOR. ETC.
ENTR.
FIRST FLOOR
NURSING SURGICAL
NURSING MATERNITY
SURGERY
UTILITY, SERV. FACIL.
STORAGE, DUCTS, ETC.
DELIVERY, NURSERY
SECOND FLOOR
NURSING MEDICAL DERM. ISO.
NURSING S.O.Q.
UTILITY, SERV. FAC.
KITCHEN DINING
STORAGE DUCTS, ETC.
THIRD FLOOR
ROOF
OFFICES, STOR., SHOPS
FOURTH FLOOR
PROTECTED AREA
SECTION

CONCEPT 5

CHAPTER EIGHT SUBSISTANCE BUILDING

ANALYSIS

ANALYSIS

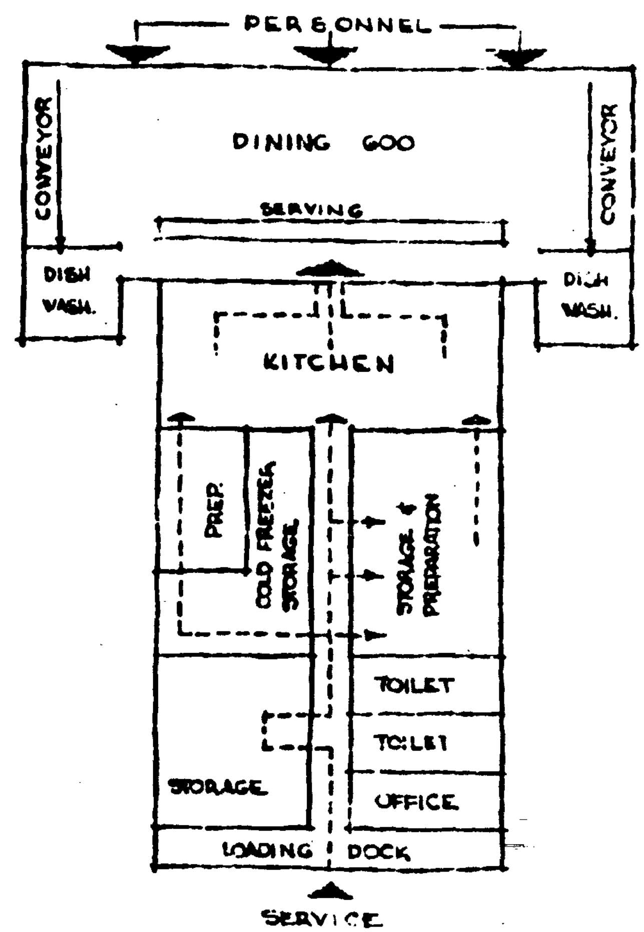
CONVENTIONAL REQUIREMENTS

The conventional subsistence building is a one-story structure without basement. The total area is 27,710 square feet and the space is divided into three major parts according to their functional use:

(1) Storage, preparation, and kitchen	12,000 sq. ft.
(2) Dining facilities	13,900 sq. ft.
(3) Dishwashing	1,600 sq. ft.

The storage area is divided into a large number of spaces serving various purposes. In addition to refrigeration and freezer units, there are general storage rooms, trash rooms, lavatories (locker rooms) for both sexes and an office. See the Schematic Plan for area requirements.

The kitchen is treated as one large room for the various general preparation and cooling facilities. However, the preparation of meat, vegetables, and baking, is located in a functional relationship to the storage areas, as well as the kitchen and possibly directly to serving. Included in the kitchen facilities is also a pot washing room. The dining room is one large space which is designed to seat approximately 600 persons at one sitting. Serving facilities are located within this general area and are cafeteria type.



SCHEMATIC PLAN OF MAJOR BUILDING COMPONENTS

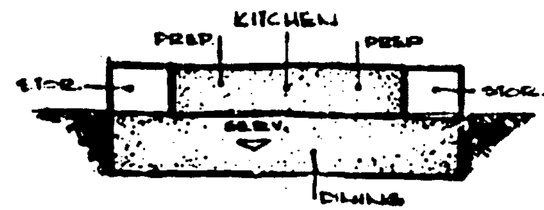
Dishwashing is divided into two units (one at each end of the dining hall) with a conveyor belt for soiled dishes. Clean dishes are distributed directly to the serving facilities.

SHELTER CONVERTIBILITY

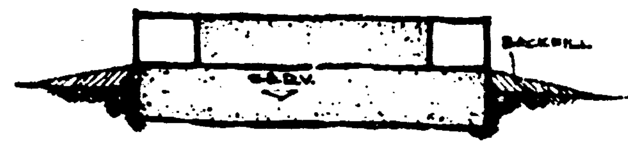
The conventional subsistence building will permit little or no protection from radioactive fallout, even with considerable and expensive modifications. This is due to the large one story plan which is subject to extensive roof and ground contribution regardless of material mass thickness in walls and roof. Some protection, however, can be found in certain interior storage rooms but these spaces are poorly suited for convertible shelter. The conventional plan is easier modified for low level inherent blast protection due to the building shape and construction.

GENERAL PHILOSOPHY

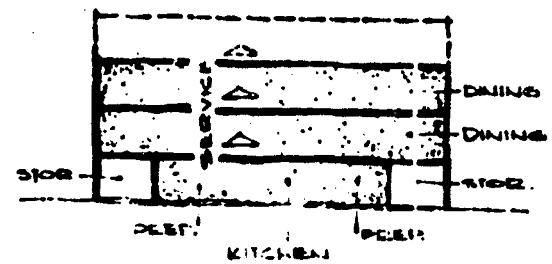
The strict functional requirements of a subsistence building, along with the large capacity, will limit the planning variation. The main criteria is smooth operation. This operation is achieved by the application of the assembly line principle. A horizontal service line from storage through preparation, cooking, and serving seems to offer the best solution, but certainly does not exclude a vertical service system. The conventional plan has a sound



BASEMENT SOLUTION



POSSIBLY LESS EXCAVATED



MULTISTORY SOLUTION

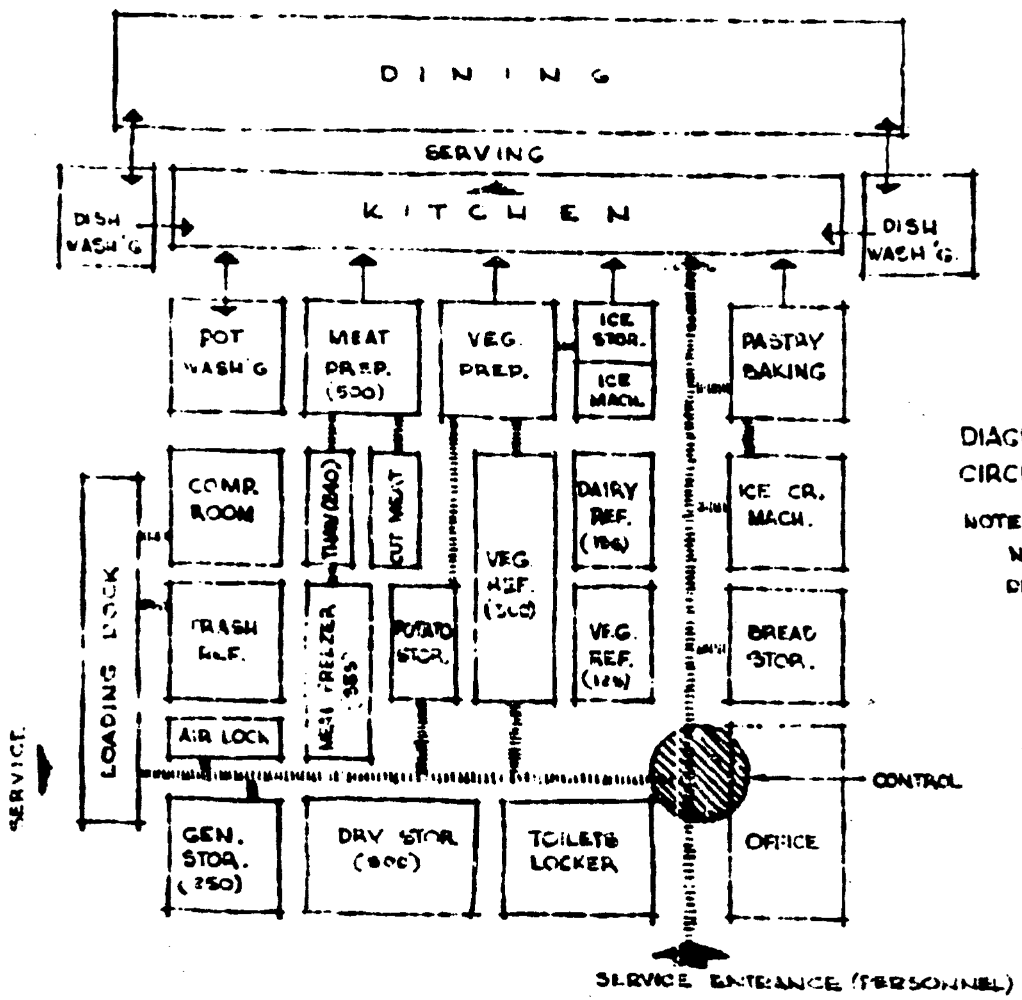
approach in its one-story layout, but is not adaptable to convertible shelter. This building has two basic requirements for convertible shelter which are already fulfilled: (1) considerable storage facilities and space for food preparation and service, and (2) large spaces available for shelter (easily removable furniture and equipment in the dining areas). However, protection is essential for survival and whether one should sacrifice efficiency in the assembly line system (preparation — cooking — serving) in order to obtain a building better suited for convertible shelter, becomes an important question. The above facilities and also the dining rooms will function effectively as interior spaces, but adequate protection can only be obtained economically by vertical planning, and thus the functions will be dependent on virtical circulation. Various solutions are possible:

(1) Storage, preparation, and kitchen facilities on the first floor with dining areas in the basement will depend upon ground conditions and has limited applications. Storage areas can provide shielding for preparation and kitchen.

(2) Storage, etc., as above but dining areas as interior rooms on two or three upper floors.

<u>Conclusion</u>

If an efficient circulation and relationship of the various functional spaces (shown on the next page as a schematic diagram) can be combined with adequate protection, the Subsistance Building will provide sound convertible shelters for a large number of men. It thus becomes a matter of decision based on the specific circumstances existing at the Naval Base in question. When the total Base capacity can be protected in other buildings such as the barracks and the training school, there may be no reason to sacrifice function and added expense to the construction of shelter in the Subsistance Building. However, if the Base is to provide shelter for a larger capacity, it may be a logical solution to utilize the existing facilities in the Subsistance Building instead of planning single purpose mass shelters. Many of those decisions cannot be made until a total complex, or Naval Base analysis for shelter is made. Such analysis depends greatly upon the local situation.



DIAGRAMMATIC LAYOUT OF CIRCULATION & AREAS

NOTE.
NUMBERS IN ( ) DESIGNATE SQ. FT

CHAPTER NINE COMMUNICATIONS BUILDING

ANALYSIS

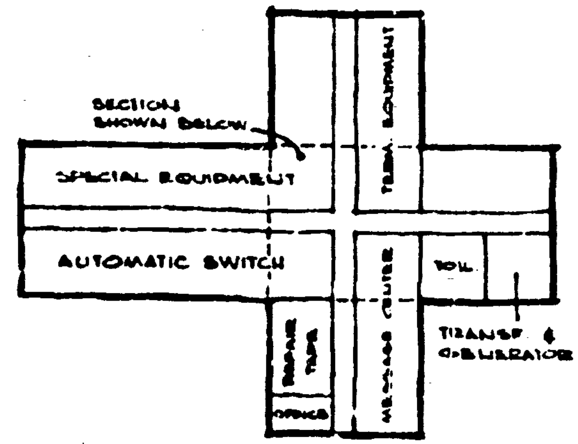
ANALYSIS

CONVENTIONAL REQUIREMENTS

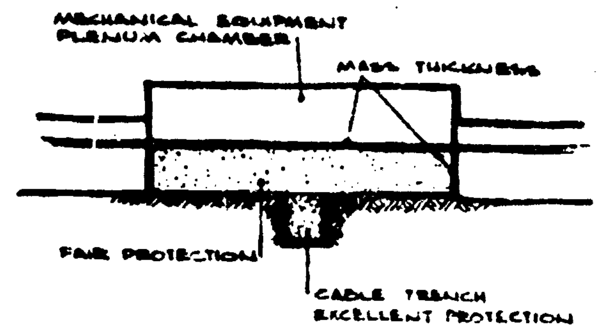
The conventional Communications Building is a large one-story structure without basement. The total area is 33,600 square feet and the floor plan is cross shaped with central corridor systems. Cable trenches are located full length under the corridor. The building is based on complete air conditioning inasmuch as it is designed without windows. A large percentage of the building will be occupied by special automatic equipment and a relatively small number of personnel will be working in the building as compared to the floor area.

SHELTER CONVERTIBILITY

Basically, a large one-story building does not lend itself to protection against radioactivity. However, with certain modifications, such as the use of a good protective material in the walls and roof, possibly combined with a washdown system to minimize roof contribution, the windowless building may give a fair protection from radiation and low level blast. Specific core areas will provide a better protection factor especially if the mechanical equipment plenum chamber in the central section (see sketch) can be designed with a floor that will give added mass thickness. In the conventional plan, the subterranean cable trenches will provide excellent protection against high level radiation. This space may be used as an initial shelter space when high intensity radiation exists and also as sleeping quarters for a prolonged shelter stay. The



FLOOR PLAN



SECTION

conventional plan cannot, however, meet the requirements for effective shielding and adequate protection for an emergency center with continued and full operation.

GENERAL PHILOSOPHY

Due to its highly specialized function, the Communication Building will have to be treated as an all operational building, whether normal or emergency conditions exist, and cannot be considered a good example for a convertible shelter solution. Under any circumstances, the building will not permit occupancy by persons other than those directly engaged in the functional activities. Personnel and equipment necessary for continual operation will need protection in order to perform their duty. Thus, the Communication Building will create a special problem similar to that of the Hospital and Administration Building. However, the last two mentioned have more flexibility in the approach of the internal emergency operation than is the case with the Communication Building. As mentioned above, the conventional plan may give some protection depending upon the amount of modification.

In the planning of this building, it is necessary to emphasize the functional grouping of the internal spaces:
(1) the spaces occupied by equipment fully and partly automatic and which do not need constant and prolonged personnel attendance, and (2) the spaces that will provide environment for human occupancy for a long duration (work, rest, and sleep). Obviously, for personal protection, the latter needs better protection than the first. In fact, the first category of spaces may well serve as an added shield between the outside contaminated areas and the internal environment.

This becomes a very important consideration when the building is to be designed as a structure partly or fully above ground. If a complete underground Communication Building with a high protection is needed, this division of spaces is obviously less important.

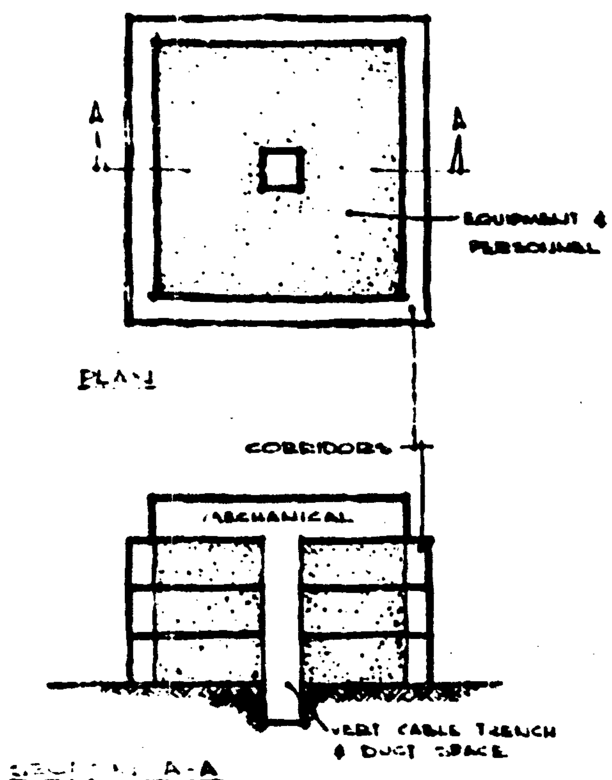
Conclusion

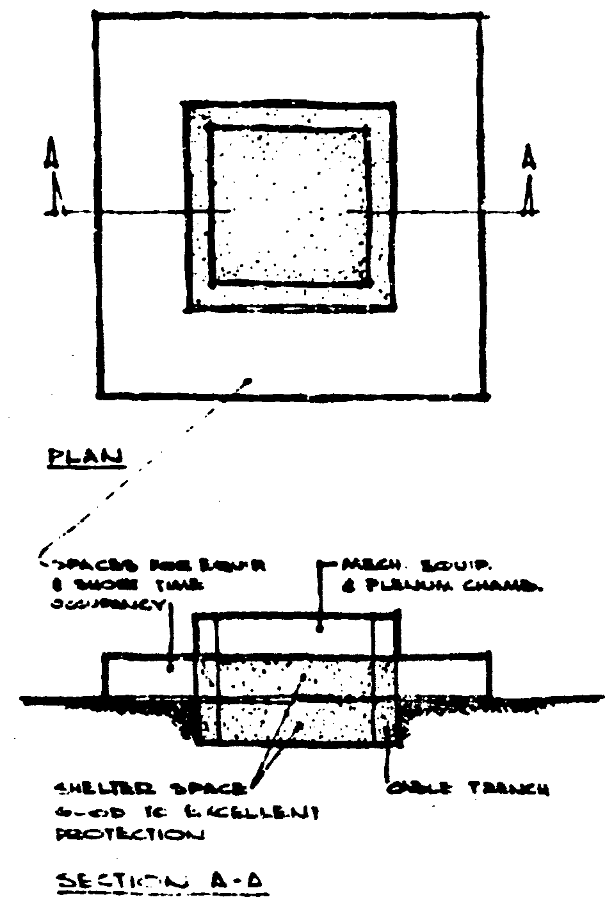
Since the building as such, does not adapt itself to convertible shelter, but rather is a permanent single purpose shelter, the problem does not fall under the objectives of this guidebook. Therefore, only brief examples of possible solutions to improve an effective and well-protected emergency operational communication center will be developed:

(1) Modification of the conventional one-story cross-shaped plan may include a simplification of the basic layout. Thus, a square or rectangular plan with an interior core for long term occupancy is possible and should not decrease the functional efficiency. This will include a core with adequate protection from roof contribution by means of mass thickness above the first floor. A possible solution may also include an enlargement of the cable trench at the central core location and obtain additional high protection for the personnel.

(2) A two story or multistory plan can also be a solution with or without a basement. However, due to mechanical equipment — cable space etc., this type of a solution will be more expensive. Although a better protection may be achieved, a multistory solution is questionable for this type of building.

(3) Where the function of the Communications Building demands a very high protection from nuclear weapons, due to the general location or strategic importance of the center, a complete underground building may be the only solution.





APPENDIX A - GLOSSARY

ABSORPTION COEFFICIENT: A number characterizing the ability of a given material to absorb radiations of a specified energy. The linear absorption coefficient expresses this ability per unit thickness and is stated in units of reciprocal length (or thickness). The mass absorption coefficient is equal to the linear absorption coefficient divided by the density of the absorbing material; it is a measure of the absorption ability per unit mass.

AFTERWINDS: Wind currents set up in the vicinity of a nuclear explosion directed toward the burst center, resulting from the updraft accompanying the rise of the fireball.

AIR BURST: The explosion of a nuclear weapon at such a height that the expanding ball of fire does not touch the earth's surface when the luminosity is a maximum (in the second pulse). A typical airburst is one for which the height of burst is such as may be expected to cause blast destruction in an average city.

ALPHA PARTICLE: A particle emitted spontaneously from the nuclei of some radioactive elements. It is identical with a helium nucleus, having a mass of four units and an electric charge of two positive units. (See Radioactivity).

ATOM: The smallest (or ultimate) particle of an element that still retains the characteristics of that element. Every atom consists of a positively charged central nucleus, which carries nearly all the mass of the atom, surrounded by a number of negatively charged electrons, so that the whole system is electrically neutral. (See Electron, Nucleus.)

ATOMIC BOMB (OR WEAPON): A term sometimes applied to a nuclear weapon utilizing fission energy only. (See Fission, Nuclear Weapon).

ATOMIC CLOUD: An all-inclusive term for the mixture of hot gases, smoke, dust, and other particulate matter from the bomb itself and from the environment, which is carried aloft in conjunction with the rising ball of fire produced by the detonation of a nuclear (or atomic) weapon.

ATOMIC WEIGHT: The relative weight of an atom of the given element. As a basis of reference, the atomic weight of oxygen is taken to be exactly 16; the atomic weight of hydrogen (the lightest element) is then 1.008. Hence, the atomic weight of any element is approximately the weight of an atom of that element relative to the weight of a hydrogen atom.

BACKGROUND RADIATION: Nuclear (or ionizing) radiation arising from within the body and from the surroundings to which individuals are always exposed. The main sources of the natural background radiation are cosmic rays, potassium - 40, thorium, uranium, and their decay products (including radium) present in rocks.

BALL OF FIRE (OR FIREBALL): The luminous sphere of hot gases which forms a few millionths of a second after a nuclear (or atomic) explosion and immediately starts to

expand and cool. The exterior of the ball of fire is initially sharply defined by the luminous shock front (in air) and later by the limits of the hot gases themselves.

BETA PARTICLE: A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Most (if not all) of the fission fragments emit negative beta particles. Physically, the beta particle is identical with an electron moving at high velocity. (See Electron, Fission Products, Radioactivity).

BLAST LOADING. The loading (or force) on an object caused by the air blast from an explosion striking and flowing around the object. It is a combination of overpressure (or diffraction) and dynamic pressure (or drag) loading. (See Diffraction, Drag, Dynamic Pressure, Overpressure).

BLAST SCALING LAWS: Formulas which permit the calculation of the properties, e.g., overpressure, dynamic pressure, time of arrival and duration of a blast wave at any distance from an explosion of specified energy from the known variation with distance of these properties for a reference explosion of known energy, e.g., of 1 kiloton. (See Cube Root Law).

BLAST WAVE: A pressure pulse of air, accompanied by winds, propagated continuously from an explosion. (See Shock Wave).

BOMB DEBRIS: The residue of a nuclear (or atomic) bomb after it has exploded. It consists of the material used for the casing and other components of the bomb, together with unexpanded fissionable materials (isotopes of uranium and plutonium) and fission products.

CHEMICAL DOSIMETER: A self-indicating device for determining total (or accumulated) radiation exposure dose based on color changes accompanying chemical reactions induced by the radiation.

CLOUD COLUMN: The visible column of smoke extending upward from the point of burst of a nuclear (or atomic) weapon. The cloud column from an air burst may extend to the tropopause, i.e., the boundary between the troposphere and the stratosphere. (See Atomic Cloud).

CONTAMINATION: The deposit of radioactive material on the surfaces of structures, areas, objects, or personnel, following a nuclear (or atomic) explosion. This material generally consists of fallout in which fission products and other bomb debris have become incorporated with particles of dirt. Contamination can also arise from the radioactivity induced in certain substances by the action of bomb neutrons. (See Bomb Debris, Decontamination, Fallout, Induced Radioactivity).

CUBE ROOT LAW: A scaling law applicable to many blast phenomena. It relates the time and distance at which a given blast effect is observed to the cube root of the energy yield of the explosion.

CURIE: A unit of radioactivity. It is the quantity of any radioactive species in which 3.700×10^{10} nuclear disintegrations occur per second. The gamma curie is sometimes defined correspondingly as the quantity of material

in which this number of disintegrations per second are accompanied by the emission of gamma rays.

DECAY (OR RADIOACTIVE DECAY): The decrease in activity of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, sometimes accompanied by gamma radiation. (See Half-Life, Radioactivity).

DECONTAMINATION: The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface so as to remove or decrease the contamination; (2) letting the material stand so that the radioactivity is decreased as a result of natural decay; and (3) covering the contamination so as to attenuate the radiation emitted. Radioactive material removed in process (1) must be disposed of by burial on land or at sea, or in other suitable ways.

DIFFRACTION: The bending of waves around the edges of objects. In connection with a blast wave impinging on a structure, diffraction refers to the passage around and envelopment of the structure by the blast wave. Diffraction loading is the force (or loading) on the structure during the envelopment process.

DOSAGE: See Dose.

DOSE: A total or accumulated quantity of ionizing (or nuclear) radiation. The term dose is often used in the sense of the exposure dose, expressed in roentgens, which is a measure of the total amount of ionization that the quantity of radiation could produce in air. This should be distinguished from the absorbed dose, given in reps or rads, which represents the energy absorbed from the radiation per gram of specified body tissue. Further, the biological dose, in rems, is a measure of the biological effectiveness of the radiation exposure. (See RBE, Rem, Rep, Roentgen).

DOSE RATE: As a general rule, the amount of ionizing (or nuclear) radiation to which an individual would be exposed per unit of time. It is usually expressed as roentgens per hour or in multiples or submultiples of these units, such as milliroentgens per hour. The dose rate is commonly used to indicate the level of radioactivity in a contaminated area.

DOSIMETER: An instrument for measuring and registering total accumulated exposure to ionizing radiations.

DRAG LOADING: The force on an object or structure due to the transient winds accompanying the passage of a blast wave. The drag pressure is the produce of the dynamic pressure and a coefficient which is dependent upon the shape (or geometry) or the structure or object. (See Dynamic Pressure.)

DYNAMIC PRESSURE: The air pressure which results from the mass air flow (or wind) behind the shock front of a blast wave. It is equal to the product of half the density of the air through which the blast wave passes and the square of the particle (or wind) velocity in the wave as it impinges on the object or structure.

ELECTRON: A particle of very small mass, carrying a

unit negative or positive charge. Negative electrons, surrounding the nucleus, are present in all atoms; their number is equal to the number of positive charges (or protons) in the particular nucleus. The term electron, where used alone, commonly refers to these negative electrons. A positive electron is usually called a positron, and a negative electron is sometimes called a negatron. (See Beta Particle).

FALLOUT: The process or phenomenon of the fall back into the earth's surface of particles contaminated with radioactive material from the atomic cloud. The term is also applied in a collective sense to the contaminated particulate matter itself.

FILM BADGE: A small metal or plastic frame, in the form of a badge, worn by personnel, and containing X-ray (or similar photographic) film for estimating the total amount of ionizing (or nuclear) radiation to which an individual has been exposed.

FIREBALL: (See Ball of Fire.)

FIRE STORM: Stationary mass fire, generally built-up urban areas, generating strong, inrushing winds from all sides, which keep the fires from spreading while adding fresh oxygen to increase their intensity.

FISSION: The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial amounts of energy. The most important fissionable materials are uranium - 235 and plutonium - 239.

FISSION PRODUCTS: A general term for the complex mixture of substances produced as a result of nuclear fission. A distinction should be made between these and the direct fission products or fission fragments which are formed by the actual splitting of the heavy-element nuclei. Something like 80 different fission fragments result from roughly 40 different modes of fission of a given nuclear species, e.g., uranium - 235 or plutonium - 239. The fission fragments, being radioactive, immediately begin to decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains about 200 different isotopes of over 30 elements.

FLASH BURN: A burn caused by excessive exposure (of bare skin) to thermal radiation. (See Thermal Radiation).

FUSION: The process whereby the nuclei of light elements, especially those of the isotopes of hydrogen, namely, deuterium and tritium, combine to form the nucleus of a heavier element with the release of substantial amounts of energy. (See Termonuclear).

GAMMA RAYS (OR RADIATIONS): Electromagnetic radiations of high energy originating in atomic nuclei and accompanying many nuclear reactions, e.g., fission, radioactivity, and neutron capture. Physically, gamma rays are identical fwith X-rays of high energy, the only essential difference being that the X-rays do not originate from atomic nuclei, but are produced in other ways, e.g., by slowing down (fast) electrons of high energy.

GROUND ZERO: The point on the surface of land or

water vertically below or above the center of a burst of a nuclear (or atomic) weapon; frequently abbreviated to GZ. For a burst over or under water, the term surface zero should preferably be used.

HALF LIFE: The time required for the activity of a given radioactive species to decrease to half of its initial value due to radioactive decay. The half-life is a characteristic property of each radioactive species and is independent of its amount or condition. The biological half-life is the time required for the amount of a specified element which has entered the body (or a particular organ) to be decreased to half of its initial value as a result of natural biological elimination processes. The effective half-life of a given isotope is the time in which the quantity in the body will decrease to half as a result of both radioactive decay and biological elimination.

HALF-VALUE LAYER THICKNESS: The thickness of a given material which will absorb half the gamma radiation incident upon it. This thickness depends on the nature of the material—it is roughly inversely proportional to its density—and also upon the energy of the gamma rays.

HEIGHT OF BURST: The height above the earth's surface at which a bomb is detonated in the air. The optimum height of burst for a particular target (or area) is that at which it is estimated a weapon of a specified energy yield will produce a certain desired effect over the maximum possible area.

HOT SPOT: Region in a contaminated area in which the level of radioactive contamination is somewhat greater than in neighboring regions in the area (See Contamination).

HYDROGEN BOMB (OR WEAPON): A term sometimes applied to nuclear weapons in which part of the explosive energy is obtained from nuclear fusion (or thermonuclear) reactions. (See Fusion, Nuclear Weapon, Thermonuclear).

INDUCED RADIOACTIVITY: Radioactivity produced in certain materials as a result of nuclear reactions, particularly the capture of neutrons, which are accompanied by the formation of unstable (radioactive) nuclei. The activity induced by neutrons from a nuclear (or atomic) explosion in materials containing the elements sodium, manganese, silicon, or aluminum may be significant.

INITIAL NUCLEAR RADIATION: Nuclear radiation (essentially neutrons and gamma rays) emitted from the ball of fire and the cloud column during the first minute after a nuclear (or atomic) explosion. The time limit of one minute is set, somewhat arbitrarily, as that required for the source of the radiations (fission products in the atomic cloud) to attain such a height only insignificant amounts reach the earth's surface. (See Residual Nuclear Radiation).

INTERNAL RADIATION: Nuclear radiation (alpha and beta particles and gamma radiation) resulting from radioactive substances in the body. Important sources are iodine - 131 in the thyroid gland, and strontium - 90 and plutonium-239 in the bone.

IONIZING RADIATION: Electromagnetic radiation

(gamma rays or X-rays) or particulate radiation (alpha particles, beta particles, neutrons,) capable of producing ions, (electrically charged particles,) directly or indirectly in its passage through matter.

ISOTOPES. Form of the same element having identical chemical properties but differing in atomic mass.

KILOTON ENERGY: The energy of a nuclear (or atomic) explosion which is equivalent to that produced by the explosion of 1 kiloton. (1,000 tons) of TNT, i.e., 10^{12} calories or 4.2×10^{19} ergs. (See Megaton Energy, TNT Equivalent).

LD-50, LD/50, or LD_{50}: Abbreviation for median lethal dose. (See Median Lethal Dose).

MAXIMUM PERMISSIBLE EXPOSURE (OR MPE): The total amount of radiation exposure which it is believed a normal person may receive day-by-day without any harmful effects becoming evident during his lifetime.

MEDIAN LETHAL DOSE: The amount of ionizing (or nuclear) radiation exposure over the whole body which it is expected would be fatal to 50 percent of a large group of living creatures or organisms. It is commonly (although not universally) accepted at the present time, that a dose of about 450 roentgens, received over the whole body in the course of a few hours or less, is the median lethal dose for human beings.

MEGATON ENERGY: The energy of a nuclear (or atomic) explosion which is equivalent to 1,000,000 tons of TNT, i.e., 10^{15} calories or 4.2×10^{22} ergs. (See TNT Equivalent).

MEV (OR MILLION ELECTRON VOLTS): A unit of energy commonly used in nuclear physics. It is equivalent to 1.6×10^{-6} erg. Approximately 200 Mev of energy are produced for every nucleus that undergoes fission.

NEUTRON: A neutral particle, (with no electrical charge), of approximately unit atomic mass, present in all atomic nuclei, except those of ordinary (or light) hydrogen. Neutrons are required to initiate the fission process and large numbers of neutrons are produced by both fission and fusion reactions in nuclear (or atomic) explosions.

NUCLEAR RADIATION: Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from the weapons standpoint, are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, but the reverse is not true; X-rays, for example, are included among ionizing radiations, but they are not nuclear radiations since they do not originate from atomic nuclei. (See Ionizing Radiation).

NUCLEAR WEAPON (OR BOMB): A general name given to any weapon in which the explosion results from the energy released by reactions involving atomic nuclei, either fission or fusion or both. Thus, the A (or atomic) bomb and the H (or hydrogen) bomb are both nuclear weapons. It would be equally true to call them atomic weapons, since it is the energy of atomic nuclei that is involved in each case. However, it has become more-

or-less customary, although it is not strictly accurate, to refer to weapons in which all the energy results from fission as A bombs or atomic bombs. In order to make a distinction, those weapons in which part, at least, of the energy results from thermonuclear (fusion) reactions among the isotopes of hydrogen have been called H bombs or hydrogen bombs.

NUCLEUS (OR ATOMIC NUCLEUS): The small, central, positively charged region of an atom which carries essentially all the mass. Except for the nucleus of ordinary (light) hydrogen, which is a single proton, all atomic nuclei contain both protons and neutrons. The number of protons determines the total positive charge, or atomic number; this is the same for all the atomic nuclei of a given chemical element. The total number of neutrons and protons, called the mass number, is closely related to the mass (or weight) of the atom. The nuclei of isotopes of a given element contain the same number of protons, but different number of neutrons. They thus have the same atomic number, and so are the same element, but they have different mass numbers (and masses) The nuclear properties, e.g., radioactivity, fission, and neutron capture, of an isotope of a given element are determined by both the number of neutrons and the number of protons. (See Atom, Isotope, Neutron, Proton).

OVERPRESSURE: The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock (or blast wave from an explosion.) The variation of the overpressure with time depends on the energy yield of the explosion, the distance from the point of burst, and the medium in which the weapon is detonated. The peak overpressure is the maximum value of the overpressure at a given location and is generally experienced at the instant the shock (or blast) wave reaches that location (See Shock Wave).

PROTON: A particle of approximately unit atomic mass carrying a unit positive charge. All atomic nuclei contain protons.

RAD: A unit of absorbed dose of radiation, 100 ergs of absorbed energy per gram.

RADIOACTIVITY: The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an (unstable) isotope. As a result of this emission, the radioactive isotope is converted (or decays)into the isotope of a different element which may (or may not) also be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (nonradioactive) end product is formed.

RBE (OR RELATIVE BIOLOGICAL EFFECTIVENESS): The radio of the number of rads of gamma (or X) radiation of a certain energy which will produce a specified biological effect to the number of rads of another radiation required to produce the same effect as the RBE of this latter radiation.

REM: A unit of biological dose of radiation; the name is derived from the initial letters of the term "roentgen equivalent man (or mammal)." The number of rems of radiation is equal to the number of rads absorbed multiplied by the RBE of the given radiation (for a specified effect).

REP: A unit of absorbed dose of radiation; the name is derived from the initial letters of the term "roentgen equivalent physical." Basically, the rep is intended to express the amount of energy absorbed per gram of soft tissue as a result of exposure to 1 roentgen of gamma (or X) radiation. This is estimated to be about 97 ergs, although the actual value depends on certain experimental data which are not precisely known. The rep is thus defined, in general, as the dose of any ionizing radiation which results in the absorption of 97 ergs of energy per gram of soft tissue. For soft tissue, the rep and the rad are essentially the same. (See Rad, Roentgen).

RESIDUAL NUCLEAR RADIATION: Nuclear radiation, chiefly beta particles and gamma rays, which persists for some time following a nuclear (or atomic) explosion. The radiation is emitted mainly by the fission products and other bomb residues in the fallout, and to some extent by earth and water constituents, and other materials, in which radioactivity has been induced by the capture of neutrons. (See Fallout, Induced Radioactivity, Initial Nuclear Radiation.)

ROENTGEN: A unit of exposure dose of gamma (or X) radiation. It is defined precisely as the quantity of gamma (or X) radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit quantity of electricity of either sign. From the accepted value for the energy lost by an electron in producing a positive-negative ion pair in air, it is estimated that 1 roentgen of gamma (of X) radiation, would result in the absorption of 87 ergs of energy per gram of air.

SCATTERING: The diversion of radiation, either thermal or nuclear, from its original path as a result of interactions (or collisions) with atoms, molecules, or larger particles in the atmosphere or other medium between the source of the radiations, e.g., a nuclear (or atomic) explosion, and a point at some distance away. As a result of scattering, radiations (especially gamma rays and neutrons) will be received at such a point from many directions instead of only from the direction of the source.

SHIELDING: Any material or obstruction which absorbs radiation and thus tends to protect personnel or materials from the effects of a nuclear (or atomic) explosion. A moderately thick layer of any opaque material will provide satisfactory shielding from thermal radiation, but a considerable thickness of material of high density may be needed for nuclear radiation shielding.

SHOCK WAVE: A continuously propagated pressure pulse (or wave) in the surrounding medium which may be air, water, or earth, initiated by the expansion of the hot gases produced in an explosion. A shock wave in air is generally referred to as a blast wave, because it is similar to (and is accompanied by) strong, but transient, winds. The duration of a shock (or blast) wave is distinguished by two phases. First there is the positive (or compression) phase during which the pressure rises very sharply to a value that is higher than ambient pressure rises and then decreases rapidly to the ambient pressure. The duration of the positive phase increases and the maximum (peak) pressure decreases with increasing distance from an explosion of given energy yield. In the second phase, the negative (or suction) phase, the pressure falls below ambient and then

returns to the ambient value. The duration of the negative phase is approximately constant throughout the blast wave history and may be several times the duration of the positive phase. Deviations from the ambient pressure during the negative phase are never large and they decrease with increasing distance from the explosion. (See Overpressure).

SURFACE BURST: The explosion of a nuclear (or atomic) weapon at the surface of the land or water or at a height above the surface less than the radius of the fireball at maximum luminosity (in the second thermal pulse). An explosion in which the bomb is detonated actually on the surface is called a contact surface burst or a true surface burst. (See Air Burst).

SURVEY METER: A portable instrument, such as a Geiger counter or ionization chamber, used to detect nuclear radiation and to measure the dose rate.

THERMAL ENERGY: The energy emitted from the ball of fire as thermal radiation. The total amount of thermal energy received per unit area at a specified distance from a nuclear (or atomic) explosion is generally expressed in terms of calories per square centimeter. (See Thermal Radiation, Transmittance).

THERMAL RADIATION: Electromagnetic radiation emitted (in two pulses) from the ball of fire as a consequence of its very high temperature; it consists essentially of ultraviolet, visible, and infrared radiations. In the early stages (first pulse), when the temperature of the fireball is extremely high, the ultraviolet radiation predominates in the second pulse, the temperatures are lower and most of the thermal radiation lies in the visible and infrared regions of the spectrum.

THERMONUCLEAR: An adjective referring to the process (or processes) in which very high temperatures are used to bring about the fusion of light nuclei, such as those of the hydrogen isotopes, deuterium and tritium, with the accompanying liberation of energy. A thermonuclear bomb is a weapon in which part of the explosion energy results from thermonuclear fusion reactions. The high temperatures required are obtained by means of a fission explosion. (See Fusion).

TNT EQUIVALENT: A measure of the energy released in the detonation of a nuclear (or atomic) weapon, or in the explosion of a given quantity of fissionable material expressed in terms of the quantity of TNT which would release the same amount of energy when exploded. The TNT equivalent is usually stated in kilotons or megatons. The basis of the TNT equivalence is that the explosion of 1 ton of TNT releases 10^9 calories of energy. (See Kiloton, Megaton, Yield).

UNDERGROUND BURST: The explosion of a nuclear (or atomic) weapon with its center beneath the surface of the ground.

UNDERWATER BURST: The explosion of a nuclear (or atomic) weapon with its center beneath the surface of the water.

YIELD (OR ENERGY YIELD): The total effective energy released in a nuclear (or atomic) explosion. It is usually

expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested as nuclear radiation, thermal radiation, and shock (and blast) energy, the actual distribution being dependent upon the medium in which the explosion occurs (primarily) and also upon the type of weapon and the time after detonation.

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